Species Status Assessment Report for Frisco buckwheat (*Eriogonum soredium*) Ostler's peppergrass (*Lepidium ostleri*) Frisco clover (*Trifolium friscanum*)

Prepared by the Utah Ecological Services Field Office
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U.S. Fish and Wildlife Service. 2018. Species status assessment report for Frisco buckwheat (*Eriogonum soredium*), Ostler's peppergrass (*Lepidium ostleri*), Frisco clover (*Trifolium friscanum*). Version 1, July 2018. Utah Ecological Services Field Office, Salt Lake City, Utah. 151 pages + Appendices.

EXECUTIVE SUMMARY

This report summarizes the results of a species status assessment (SSA) that was completed for Frisco buckwheat, Ostler's peppergrass, and Frisco clover to evaluate each species' overall viability. This SSA report summarizes the current and future conditions of Frisco buckwheat, Ostler's peppergrass, and Frisco clover to assess each species' overall viability now and into the future.

To assess each species' viability, we used the three conservation biology principles of resiliency, representation, and redundancy (together, the 3Rs). For the purposes of this SSA, we define viability as the ability of Frisco buckwheat, Ostler's peppergrass, and Frisco clover to sustain wild populations into the future. Specifically, we identified the species' ecological requirements for survival and reproduction at the individual, population, and species levels, and described the stressors influencing the species' viability. We evaluated the changes in resiliency, redundancy, and representation from historical to the current time, and forecasted changes into the future.

The three species are rare endemic plants found only in Utah. Frisco buckwheat and Ostler's peppergrass occur together in three population areas in the southern San Francisco Mountains in Beaver County. Both species share the same population names of Grampian Hill, Cupric Mine, and San Francisco. Frisco clover is known from six populations in the southern San Francisco Mountains, Wah Wah Mountains, Tunnel Springs Mountains, and Beaver Lake Mountains in Beaver and Millard Counties. Frisco clover populations are Blue Mountain, Grampian Hill, San Francisco, Lime Mountain, Tunnel Springs Mountains, and Wah Wah Mountains. Frisco buckwheat, Ostler's peppergrass, and Frisco clover occupy 297 acres (ac) (120 hectares (ha)), 153 ac (62 ha), and 360 ac (146 ha) of habitat area, respectively.

Frisco buckwheat, Ostler's peppergrass, and Frisco clover are long-lived perennial plant species that flower in the spring and summer months and likely require pollinators for maximum reproduction. Plant survival and successful recruitment require suitable intact soils with microsites for establishment and growth. The low canopy coverage of associated vegetation must result in low plant competition but also appears to provide sufficient floral resources to support pollinators. The health (long-term productivity) of populations is affected by the population size, habitat quantity, and habitat quality available to support stable or increasing populations. In addition to proximity between populations, habitat connectivity is important to support gene flow within populations. At the species level, Frisco buckwheat, Ostler's peppergrass, and Frisco clover need a sufficient number and distribution of healthy populations to withstand environmental stochasticity (resiliency), catastrophes (redundancy), and biological and physical changes in their environment (representation).

To assess resiliency, we evaluated relevant habitat and demographic factors to calculate an overall condition score for each plant population. We evaluated population size, habitat area, habitat quality, and habitat loss for the current condition, and included an additional factor, climate change resilience, when evaluating the future condition. Based on the results of these evaluations we rated population condition Good, Moderate, or Low. In our assessment, high overall viability means having more populations in Good to Moderate condition. To assess redundancy, we evaluated the predicted number and distribution of populations within the species range relative to the current condition. To assess representation, we evaluate the predicted change in the number of individuals relative to the current condition.

We evaluated the change in resiliency, redundancy, and representation from the past until the present, and also projected future states of these conditions. Based on input received from Federal and state agencies, private industry, and the best available information, we developed four potential future scenarios: conservation, low to moderate level precious metal exploration and mining, moderate level stone mining, and high level stone and precious metal mining. We evaluated each of these scenarios over the next 20 years.

For each future scenario, we forecasted the biological condition using four stressors: precious metal exploration and mining, stone mining, nonnative invasive species, and climate change. Our future scenarios varied based on the potential exposure and impact of the two main stressors: precious metal exploration and mining and stone mining, as follows:

(1) Conservation Scenario – we considered the future condition of populations without impacts from precious metal exploration and mining, stone mining, and nonnative invasive species. We assumed the cessation of stone mining and precious metal exploration and mining within plant populations into the future as a result of voluntary protections. This scenario also evaluates the impact of climate change;

(2) Low to Moderate Level Precious Metal Exploration and Mining Scenario– we considered the impact of precious metal exploration and mining, nonnative invasive species, and climate change. We assumed future precious metal exploration would occur at low levels similar to historical use within plant populations. We assumed future precious metal mining would occur at moderate levels within two areas of highest development potential at mineral deposits in the San Francisco mountain range. We did not consider the impact of stone mining in this scenario so that we could evaluate the relative contribution of the precious metal and mining stressor to each species' resiliency, redundancy, and representation;

(3) Moderate Level Stone Mining Scenario – we considered the impact of stone mining expansion at existing mines, nonnative invasive species, and climate change. We assumed future stone mining would result in greater than ten percent habitat loss and reductions to habitat area and population size. We did not consider the impact of precious metal exploration and mining in this scenario so that we could evaluate the relative contribution of the stone mining stressor to each species resiliency, redundancy, and representation; and

(4) High Level Stone and Precious Metal Mining Scenario – we considered the combined impacts of extensive stone mining at existing mines and high intensity precious metal exploration and mining within mineral deposit areas in the San Francisco mountain range, as well as nonnative invasive species, and climate change. We assumed more extensive impacts from the two mining stressors than what we considered under the low to moderate level scenarios.

We acknowledge that our assessment is a prediction and may not accurately forecast future events. However, we used the best available science for our analyses and acknowledged any key assumptions and uncertainties throughout this SSA report. Of the four scenarios, the most realistic future scenario would likely be the combination of the two mining stressors, and thus combining scenarios 2 and 3. When the two scenarios are combined, the impacts to the three plant species are identical to those described under the Moderate Level Stone Mining Scenario. We consider the resultant effects from the Moderate Level Stone Mining Scenario to be a reasonable future prediction of plant population condition without voluntary protections. Scenario 4 is the least probable future scenario of the four. Scenario 4's predicted future precious metal mining potential is too low for us to consider the resultant effects from this stressor as plausible at this time.

Overall, Frisco buckwheat, Ostler's peppergrass, and Frisco clover currently exhibit levels of resiliency, redundancy, and representation that have allowed populations to persist throughout each species entire historical range. Populations of all three species are in Good or Moderate condition, and levels of redundancy and representation are similar to what they were historically. All three species have persisted despite some historical precious metal exploration and mining, recent stone mining, and intermittent drought conditions in the western U.S. over the last 17 years. The persistence of Frisco buckwheat, Ostler's peppergrass, and Frisco clover is not a direct result of any ongoing conservation measures. Rather, the current condition is a direct result of the little to no habitat loss and degradation to-date in each species' habitat.

Our predictions of each species' future viability vary between the Conservation, Low to Moderate Level Precious Metal Exploration and Mining, Moderate Level Stone Mining, and High Level Stone and Precious Metal Mining Scenarios (Tables 1, 2, and 3), as described below. The resiliency of Frisco buckwheat and Ostler's peppergrass are identical for a given scenario because they share similar ranges, population distributions, exposure to stressors, and responses to stressors. Frisco clover has less exposure to stone mining and precious metal exploration and mining due to the species' larger range. For both mining stressors, we also identified specific conservation measures that will improve population condition based on our future condition metrics with less extensive future stone mining and precious metal exploration and mining.

The future viability of the three species under the Conservation Scenario is similar to the current condition due to the removal of the mining stressors in the populations. Under the Conservation Scenario, we predict that populations of each species would continue to occupy existing habitat, they would be resilient, and they would maintain a stable condition. Under the Conservation Scenario, the Grampian Hill population for Ostler's peppergrass and Frisco clover ranked highest for predicted climate change resiliency compared to all other plant populations. The only plant population of the three species with a predicted reduction in future condition due to climate change resiliency was the Frisco clover Lime Mountain population. Levels of redundancy and representation for the three species are predicted to be similar to what they are currently due to the same number and distribution of populations, and stable population sizes.

Table 1. Summary of Frisco buckwheat overall condition scores (Low, Moderate, Good) under the current scenario and four future scenarios. Metrics for evaluating current and future condition are identified in Table 17 and Table 25, respectively. (*There is greater exposure to stone mining and precious metal exploration and mining impacts under the High Level Stone and Precious Metal Mining Scenario).

Population	Estimated Population Size (Percent of Total Population)	Mining Stressors	Overall Current Condition (Resiliency)	Conservation Future Condition (Resiliency)	Low to Moderate Level Precious Metal Exploration and Mining Future Condition (Resiliency)	Moderate Level Stone Mining Future Condition (Resiliency)	High Level Stone and Precious Metal Mining Future Condition (Resiliency)
Grampian Hill	20,000 (26%)	Precious metal exploration and mining	Good	Good	Good	Good	Low
Cupric Mine	1,000 (1%)	Stone mining; Precious metal exploration and mining	Moderate	Moderate	Moderate	Low	Low
San Francisco	57,500 (73%)	Stone mining at Indian Queen subpopulation; Precious metal exploration and mining at Copper Gulch subpopulation*	Good	Good	Good	Moderate	Moderate

Table 2. Summary of Ostler's peppergrass overall condition scores (Low, Moderate, Good) under the current scenario and four future scenarios. Metrics for evaluating current and future condition are identified in Table 17 and Table 25, respectively. (*There is greater exposure to stone mining and precious metal exploration and mining impacts under the High Level Stone and Precious Metal Mining Scenario).

Population	Estimated Population Size (Percent of Total Population)	Mining Stressors	Overall Current Condition (Resiliency)	Conservation Future Condition (Resiliency)	Low to Moderate Level Precious Metal Exploration and Mining Future Condition (Resiliency)	Moderate Level Stone Mining Future Condition (Resiliency)	High Level Stone and Precious Metal Mining Future Condition (Resiliency)
Grampian Hill	2,000 (5%)	Precious metal exploration and mining	Good	Good	Good	Good	Low
Cupric Mine	1,000 (2%)	Stone mining; Precious metal exploration and mining	Moderate	Moderate	Moderate	Low	Low
San Francisco	39,000 (93%)	Stone mining at Indian Queen subpopulation; Precious metal exploration and mining at Copper Gulch subpopulation*	Good	Good	Good	Moderate	Moderate

Table 3. Summary of Frisco clover overall condition scores (Low, Moderate, Good) under the current scenario and four future scenarios. Metrics for evaluating current and future condition are identified in Table 17 and Table 25, respectively. (*There is greater exposure to stone mining and precious metal exploration and mining impacts under the High Level Stone and Precious Metal Mining Scenario).

Population	Estimated Population Size (Percent of Total Population)	Mining Stressors	Overall Current Condition (Resiliency)	Conservation Future Condition (Resiliency)	Low to Moderate Level Precious Metal Exploration and Mining Future Condition (Resiliency)	Moderate Level Stone Mining Future Condition (Resiliency)	High Level Stone and Precious Metal Mining Future Condition (Resiliency)
Blue Mountain	250 (2%)	Stone mining	Moderate	Moderate	Moderate	Low	Low
Grampian Hill	5,000 (32%)	Precious metal exploration and mining	Good	Good	Good	Good	Low
San Francisco	4,300 (27%)	Precious metal exploration and mining*	Good	Good	Good	Good	Good
Lime Mountain	625 (4%)	No mining	Good	Moderate	Moderate	Moderate	Moderate
Tunnel Springs Mountains	2,500 (16%)	No mining	Good	Good	Good	Good	Good
Wah Wah Mountains	3,000 (19%)	No mining	Good	Good	Good	Good	Good

Under the Low to Moderate Level Precious Metal Exploration and Mining Scenario, we predict resilient populations in stable condition for Frisco buckwheat, Ostler's peppergrass, and Frisco clover, due to the low impact of future exploration in plant populations and the location of moderate levels of future precious metal mining outside of plant populations. We conclude that future precious metal exploration does not negatively impact the resiliency of plant populations when impacts are similar to historical levels. Levels of redundancy and representation for the three species are predicted to be similar to what they are currently due to the same number and distribution of populations, and stable population sizes. We have high certainty that precious metal exploration activities will continue into the future. We are uncertain about the likelihood of future precious metal mining and associated impacts even though we include future mining in this scenario. We will have higher certainty about the potential likelihood of future precious metal mining within the next year based on the results of current exploration at deposit areas in the San Francisco mountain range. If the exploration results do not locate mineable deposits, it is unlikely that precious metal mining will occur in the near future.

Under the Moderate Level Stone Mining Scenario, we predict declines in resiliency for two populations each of Frisco buckwheat and Ostler's peppergrass (Cupric Mine and San Francisco) and one population of Frisco clover (Blue Mountain) due to population size reductions and habitat loss. Stone mining has a larger impact to resiliency for small plant populations (Frisco buckwheat and Ostler's peppergrass at Cupric Mine, and Frisco clover at Blue Mountain) than larger populations (Frisco buckwheat and Ostler's peppergrass at San Francisco). We predict stone mining impacts will result in Low condition of the two small populations and Moderate condition of the larger populations. The resiliency of the other plant populations (Frisco buckwheat and Ostler's peppergrass Grampian Hill; Frisco clover Grampian Hill, San Francisco, Lime Mountain, Tunnel Springs Mountains, Wah Wah Mountains) will remain the same as the Conservation Scenario. We predict impacts to representation for the three species but not a decrease in redundancy. Impacts to representation depend on the extent of stone mining in plant populations. We have high certainty that stone mining will continue into the future at existing mines.

Under the High Level Stone and Precious Metal Mining Scenario, we predict declines in resiliency for all three populations of Frisco buckwheat and Ostler's peppergrass and two populations of Frisco clover (Grampian Hill and Blue Mountain) due to population size reductions and habitat loss. We predict extensive stone mining impacts will result in the same declines in resiliency as the Moderate Level Stone Mining Scenario for the two populations each of Frisco buckwheat and Ostler's peppergrass (Cupric Mine and San Francisco) and one population of Frisco clover (Blue Mountain). Extensive precious metal mining impacts under this scenario result in a large impact to the resiliency of the Grampian Hill populations for all three species. We predict extensive precious metal exploration and mining impacts will result in Low condition of the three Grampian Hill populations. We predict extensive impacts to representation for the three species from both mining stressors. Redundancy is predicted to decrease with the loss of one population each of Frisco buckwheat and Ostler's peppergrass (Cupric Mine) and the Frisco clover (Blue Mountain) from extensive stone mining. We consider the High Level Stone and Precious Metal Mining Scenario to be a worst case scenario for future stone mining that probably does not characterize a reasonable mining extent within our evaluation timeframe. We consider the High Level Stone and Precious Metal Mining Scenario to be a worst case scenario for future precious metal exploration and mining that is only possible if a large source of copper deposit similar in size to Utah's Bingham Canyon deposit in Salt Lake County is located and mined near the Grampian Hill populations of the three species. We will have higher certainty about the potential likelihood of future precious metal mining within the next year based on the results of current exploration at the deposit areas in the San Francisco mountain range. If exploration does not locate mineable deposits, it is unlikely that precious metal mining will impact the Grampian Hill populations of the three species in the near future. However, we would expect precious metal exploration to continue.

Future climate conditions alone would not have a large effect on the future condition of populations of the three species. However, climate change has the potential to reduce the number of suitable microhabitat sites available within populations. There is also the potential for a range reduction for all three species due in part to climate change, particularly in combination with other stressors. Frisco buckwheat and Ostler's peppergrass are likely vulnerable to occupied and suitable habitat loss and degradation given their small range and small areas of occupied habitat. We assumed based on these two species small range, they have the ability to migrate to favorable microsites that are cooler and wetter, but only within their existing populations and nearby suitable habitat. We assumed based on Frisco clover's larger range and wider soil tolerance, the species may have a greater ability to migrate and establish beyond existing populations and adjacent suitable habitat. Given the three species limited ability to migrate and establish outside of their existing ranges, we recommend measures to support the adaptive capacity (representation) of the three species to develop a tolerance of future climate conditions in combination with other stressors. Suggested conservation measures include conserving plant abundance and the high quality habitat condition of occupied habitat, conserving suitable habitat within a reasonable dispersal distance of occupied habitat, and implementing assisted migration by way of pilot introductions within suitable habitat on other protected lands.

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Chapter 1. Introduction, Data, and Analytical Framework

This report summarizes the results of our species status assessment (SSA) conducted for Frisco buckwheat, Ostler's peppergrass, and Frisco clover. We conducted this SSA to compile the best available data regarding the species' biology and factors that influence the species' viability.

We, the U.S. Fish and Wildlife Service, were petitioned to list all three species as threatened or endangered under the Endangered Species Act (ESA) on July 30, 2007, by Forest Guardians (now WildEarth Guardians). A subsequent complaint was filed on March 19, 2008 for not meeting the statutory petition finding deadlines. On February 5, 2009 (74 FR 6122), we published a 90-day finding stating the petition did not present substantial scientific or commercial information indicating listing was warranted for these three species. On March 13, 2009, we and WildEarth Guardians filed a stipulated settlement in the District of Columbia Court, agreeing that we would submit to the Federal Register a finding as to whether WildEarth Guardians' petition presented substantial information indicating that the petitioned action may be warranted for 38 species by August 9, 2009 (WildEarth Guardians vs. Salazar 2009, case 1:08-CV-472-CKK). On August 18, 2009, we published a notice of 90-day finding (74 FR 41649) that the petition presented substantial scientific and commercial information for Frisco buckwheat, Ostler's peppergrass, and Frisco clover, indicating that listing may be warranted for these three species. We published a 12-month finding on February 23, 2011 (76 FR 10166) that stated listing all three species as threatened was warranted, but precluded by higher priority actions. We reviewed the status of the three species annually in our candidate notice of reviews (CNORs) (77 FR 70039, November 21, 2012; 78 FR 70145, November 22, 2013; 79 FR 72482, December 5, 2014; 80 FR 80604, December 24, 2015). The SSA will be the biological underpinning of our forthcoming decision on whether Frisco buckwheat, Ostler's peppergrass, and Frisco clover warrant protection under the ESA.

The SSA assesses the ability of Frisco buckwheat, Ostler's peppergrass, and Frisco clover to maintain populations over time (i.e., viability). To assess viability of these species, we used the three conservation biology principles of resiliency, representation, and redundancy (or the "3Rs", Shaffer and Stein 2000, pp. 308-311; section 1.2, Analytical Framework). These principles are generally described later in this chapter, and more specifically for the three species in Chapters 2 and 3. Our approach for assessing viability involved three stages. In Stage 1, we described each species' ecology in terms of the 3Rs. Specifically, we identified the ecological requirements for survival and reproduction at the individual, population, and species levels. In Stage 2, we determined the baseline condition for each species using the ecological requirements identified in Stage 1. That is, we assessed each species' historical and current condition in relation to the 3Rs and identified past and ongoing stressors or beneficial factors that led to each species' current condition. In Stage 3, using the baseline conditions established in Stage 2 and the predictions for future risk and beneficial factors, we projected the likely future condition of Frisco buckwheat, Ostler's peppergrass, and Frisco clover.

Each species' ecology (Stage 1) is summarized in Chapters 2 and 3; stressors influencing viability are summarized in Chapter 4; historical and current conditions (Stage 2) are summarized in Chapter 5; and future conditions (Stage 3) are explained in Chapter 6. Lastly, the viability of Frisco buckwheat, Ostler's peppergrass, and Frisco clover over time is described through a synthesis of historical, current, and future conditions analyses and is provided in Chapter 7.

1.1 Occurrence Data

The occurrence data used for our analyses are primarily based on compiled data from Utah Heritage Program records, published survey reports, and through coordination efforts with State agencies and species experts. We used a series of quality control checks to remove duplicative data and verify the spatial locations of plant records. We imported the data into ESRI Arc geographic information system (GIS) version 10.5.1 where geographic coordinates were projected and ESRI feature classes were created (Chapter 8).

We refined the range of Frisco buckwheat, Ostler's peppergrass, and Frisco clover by combining all documented occupied habitat. We delineated plant populations by following standardized methods used by the national network of Natural Heritage Programs to identify the species' element occurrences (EOs). EOs are plant points that are grouped together based on geographic proximity within a 2 km (1.24 miles) distance separated by suitable habitat (NatureServe 2004, p. 6). Our populations differ slightly from this protocol in a few instances where the distance slightly exceeded 2 km (1.24 miles). For the purpose of this assessment, we consider EOs to be synonymous with populations and hereafter will use the term "populations" when describing the distribution of the species. We mention that populations are comprised of subpopulations when plant locations are clustered and separated by approximately 1 km (0.62 miles). The subpopulation delineation is helpful when we evaluate impacts of mining operations to a population. In our conservation recommendation section (Chapter 5), we use another term "population area" which includes occupied habitat and suitable habitat within 2 km (1.24 miles) of occupied habitat. The population area delineation is helpful when we consider conservation of suitable habitat for the three species.

The most recent comprehensive survey and population estimate for all three species was performed in 2010 (Miller 2010a, entire; Miller 2010c, entire; Roth 2010, entire). Citations for survey reports are provided in Chapter 3. We are not able to evaluate population trends for the three species. It is difficult to compare the number of plant occurrences over time because the data were collected with different sampling methods over the years that were not always documented. For Frisco buckwheat and Ostler's peppergrass in particular, common field techniques used to estimate population size tend to be highly subjective in the absence of actual population counts because of how both species grow. Both species grow in low, mound-forming clusters, making it difficult to distinguish individual plants. Thus, some observers may assume each cluster is one plant and other observers might apply a multiplier to each cluster and count them as multiple plants. Use of either estimate method would greatly skew the resulting population estimate and we believe these biases help explain the seemingly large fluctuations in numbers of plants observed during different surveys (Chapter 3, Population Status).

1.2 Analytical Framework

To assess the viability of Frisco buckwheat, Ostler's peppergrass, and Frisco clover, we applied the conservation biology principles of resiliency, representation, and redundancy (the 3Rs) (sections 5.1, Species Resiliency, Historical and Current Condition; 5.2, Species Redundancy, Historical and Current Condition; 5.3, Species Representation, Historical and Current Condition). Viability is the ability to sustain populations over time. To do this, a species must have a sufficient number and distribution of healthy populations to withstand changes in its biological (e.g., herbivores, disease) and physical (e.g., climate change) environment, environmental stochasticity (e.g., wet or dry, warm or cold years), and catastrophes (e.g., severe and prolonged droughts). Viability is not a single state—viable or not viable; rather, there are degrees of viability—less to more viable, or low to high viability. Generally speaking, the more resiliency, representation, and redundancy a species has, the more protected it is against the vagaries of the environment, the more it can tolerate stressors (one or more factors that may be acting on the species or its habitat, causing a negative effect), the better able it is to adapt to future changes, and thus, the more viable it is. In short, we used the 3Rs framework to assess the health, number, and distribution of Frisco buckwheat, Ostler's peppergrass, and Frisco clover populations relative to frequency and magnitude of environmental stochasticity and catastrophic events across its historical range of adaptive diversity.

1.2.1. Resiliency

Species-level resiliency is the ability to sustain populations in the face of environmental variation and transient perturbations. Environmental variation includes normal year-to-year variation in rainfall and temperatures, as well as unseasonal weather events. Perturbations are stochastic events such as fire, flooding, and storms. Simply stated, resiliency is having the means to recover from "bad years" and disturbances. To be resilient at the species-level, there must be healthy populations that are able to sustain themselves through good and bad years. The healthier the populations and the greater number of healthy populations, the more resiliency a species possesses.

To be resilient at the population-level, there must be a healthy demography and sufficient quality habitat to support populations with a stable or positive growth rate over time. Generally speaking, the larger the population, the healthier and more resilient it is.

For many species, resiliency is also affected by the degree of connectivity among populations and the diversity of ecological niches occupied. Connectivity among populations increases the genetic health of individuals (heterozygosity or genetic variability) within a population and bolsters a population's ability to recover from disturbances via rescue effect (immigration). Diversity of climate niches improves a species' resiliency by guarding against disturbances and perturbations affecting all populations similarly (*i.e.*, decreases the chance of all populations experiencing bad years simultaneously or to the same extent).

1.2.2. Representation

Species-level representation is the ability of a species to adapt to near and long-term changes in the environment, and it demonstrates the evolutionary capacity or flexibility of a species. Representation is the range of variation found in a species, and this variation--called adaptive diversity--is the source of species' adaptive capabilities. Representation can, therefore, be measured through the breadth of adaptive diversity of the species. The greater the adaptive diversity, the more responsiveness and adaptable the species will be over time, and thus, the more viable the species is. Maintaining adaptive diversity includes conserving both the ecological diversity and genetic diversity of a species. Ecological diversity is the physiological, ecological, and behavioral variation exhibited by a species across its range. Genetic diversity is the number and frequency of unique alleles within and among populations. By maintaining these two sources of adaptive diversity across a species' range, the responsiveness and adaptability of a species over time is preserved.

In addition to preserving the breadth of adaptive diversity, maintaining evolutionary capacity requires maintaining the evolutionary processes that drive evolution, namely, gene flow, genetic drift, and natural selection. Gene flow is expressed through the physical transfer of genes or alleles from one population to another through immigration and breeding. The presence or absence of gene flow can directly affect the size of the gene pool available. Gene flow will generally increase genetic variation within populations by bringing in new alleles from elsewhere, but decrease genetic variation among populations by mixing their gene pools (Hendry *et al.* 2011, p. 173).

Genetic drift is the change in the frequency of alleles in a population due to random, stochastic events. Genetic drift always occurs, but is more likely to negatively affect populations that have a smaller effective population size (N_e) and populations that are geographically spread and isolated from one another. Natural selection is the process by which heritable traits can become more (selected for) or less (not selected for) common in a population based on the reproductive success of an individual with those traits. Natural selection influences the gene pool by determining the alleles that are perpetuated in particular environments. This selection process generates the unique alleles and allelic frequencies, which reflect specific ecological, physiological, and behavioral adaptations that are optimized for survival in different environments.

1.2.3. Redundancy

Species-level redundancy is the ability of a species to withstand catastrophic events. Redundancy protects species against the unpredictable and highly consequential events for which adaptation is unlikely. In short, it is about spreading the risk. Redundancy is best achieved by having multiple populations widely distributed across the species' range. Having multiple populations reduces the likelihood that all populations are affected simultaneously, while having widely distributed populations reduces the likelihood of populations possessing similar vulnerabilities to a catastrophic event. Given sufficient redundancy, single or multiple catastrophic events are unlikely to cause the extinction of a species. Thus, the greater redundancy a species has, the more viable it will be. Furthermore, the more populations and the more diverse or widespread that these populations are, the more likely it is that the adaptive diversity of the species will be preserved. Having multiple populations distributed across the range of the species, will help preserve the breadth of adaptive diversity, and hence, the evolutionary flexibility of the species.

Potential impacts to redundancy from catastrophic events can act at a variety of different scales. Catastrophic events that are associated with environmental stochasticity such as droughts and flooding act at local and regional scales, and thus populations can fluctuate in synchrony over broad geographical areas (Hanski 1999, p. 372). Landscape and habitat changes over large areas can lead to extinction risks among populations (Hanski 1999, pp. 381-382). Alternately, having populations distributed across a diversity of environmental conditions and larger geographic areas reduces the potential for concurrent losses of populations at local and regional scales. The greater degree of spatial heterogeneity (specifically, the diversity of temperature and precipitation conditions occupied by a species), the greater redundancy the species will possess.

Chapter 2. Biology and Individual Resource Needs

In this chapter, we provide biological information about Frisco buckwheat, Ostler's peppergrass, and Frisco clover, including their taxonomic history and relationships, morphological description, reproductive and other life history traits, and physical environment. We identify those aspects of the life history of the three species that are important to our analysis. We then outline the resource needs of individuals. This is not an exhaustive review of the species natural history; rather, we provide the ecological basis for the SSA analyses conducted in Chapters 5 and 6.

2.1 Species Description, Taxonomy, and Genetics

2.1.1 *Frisco buckwheat*

Frisco buckwheat was first described as *Eriogonum soredium* in 1981 by James Reveal based on a collection by Stan Welsh and Matt Chatterly (Reveal 1981, entire; Kass 1992a, p. 1). Frisco buckwheat has not undergone any taxonomic revisions since it was originally described. We accept the current taxonomy and consider Frisco buckwheat a viable species according to ESA standards. Recent field observations indicate that Frisco buckwheat (*E. soredium*) may be hybridizing (crossbreeding) with the more widely distributed Shockley buckwheat (*E. shockleyi*) in the Indian Queen subpopulation of the San Francisco population (Red Butte Garden 2015, p. 1). We do not have information regarding the genetic diversity of Frisco buckwheat. A genetics study is in progress to clarify the taxonomy and distribution of this taxon (Red Butte Garden 2015, p. 1; Wolf 2016, entire).

Frisco buckwheat is a low mound-forming perennial plant in the buckwheat family (Polygonaceae). Individual plants, particularly large cushions, appear to be long-lived, but additional studies are needed to determine the species growth, age or size of reproductive individuals, reproductive output, and lifespan. Individuals are short-statured, growing to a height of 0.8 to 1.6 inches (in.) (2 to 4 centimeters (cm)) and range in width from 3.9 to 19.7 in. (10 to 50 cm) (Welsh et al. 2008, p. 588). The leaves are 0.08 to 0.2 in. (2 to 5 millimeters (mm)) long, 0.03 to 0.08 in. (0.7 to 2 mm) wide, round to oval, and covered on both surfaces by short, white, wooly hairs (Welsh et al. 2008, p. 588). The numerous flowers are arranged in tight clusters resembling drumsticks. Individual flowers are white or partially pink and 0.08 to 0.12 in. (2 to 3 mm) long (Figure 1; Welsh et al. 2008, p. 588). Frisco buckwheat can be distinguished from the Shockley buckwheat by the presence of hairs on the flower clusters and the lack of hairs on individual flowers.

Figure 1. Frisco buckwheat in flower (Photo by Daniela Roth, Service).

2.1.2 *Ostler's peppergrass*

Ostler's peppergrass was first described as *Lepidium ostleri* in 1980 by Stan Welsh and Sherel Goodrich based on a collection by Stan Welsh and Matt Chatterly (Welsh and Goodrich 1980, entire; Kass 1992b, p. 1). Ostler's peppergrass has not undergone any taxonomic revisions since it was originally described. We accept the current taxonomy and consider Ostler's peppergrass a valid species according to ESA standards. We do not have information regarding the genetic diversity of Ostler's peppergrass.

Individual plants grow in dense cushion-like tufts up to 2 in. (5 cm) tall (Welsh *et al.* 2008, p. 328). Individual plants, particularly large cushions, appear to be long-lived, but additional studies are needed to determine the species growth, age or size of reproductive individuals, reproductive output, and lifespan. The leaves are grayish-green hairy, 0.16 to 0.59 in. (4 to 15 mm) long, generally linear, but may have lobed basal leaves (Welsh *et al.* 2008, p. 328). Flowering stalks are approximately 0.39 in. (1 cm) long with 5 to 35 flowers that are white or have a purple tint (Figure 2; Welsh *et al.* 2008, p. 328).

Figure 2. Ostler's peppergrass in fruit. Photo by Daniela Roth (Service).

2.1.3 *Frisco clover*

Frisco clover was originally described by Stanley Welsh as *T. andersonii* var. *friscanum* from specimens collected on Grampian Hill in the southern San Francisco Mountains in Beaver County, Utah (Welsh 1978, p. 355). The variety was elevated to species level in 1993 (Welsh 1993, p. 407). We accept the current taxonomy and consider Frisco clover a valid species according to ESA standards. We do not have information regarding the genetic diversity of Frisco clover.

Frisco clover plants have a taproot and thick woody stem. Individual plants, particularly larger plants, appear to be long-lived, but additional studies are needed to determine the species growth, age or size of reproductive individuals, reproductive output, and lifespan. Frisco clover grows up to 1.2 in (3 cm) tall and has silver hairy leaves composed of three leaflets (Welsh *et al.* 2008, p. 486). Its flowers resemble those of other clover species and are arranged in heads of four to nine reddish-purple flowers with pale wings (Figure 3; Welsh *et al.* 2008, p. 486).

Figure 3. Frisco clover in flower. Photo by Daniela Roth, Service.

2.2 Life History, Ecology, and Resource Needs

2.2.1 *Frisco buckwheat*

Individual plants, particularly large mounds, appear to be long-lived, but additional studies are needed to determine the species growth, age and size of reproductive individuals, reproductive output, and lifespan. In general, seed germination in the buckwheat (*Eriogonum*) genus occurs in the spring after a period of cold, moist stratification over the winter (Meyer and Paulsen 2000, p. 20 - 21). Successful germination and establishment of seedlings depends on the quality and availability of suitable microsites in the habitat (Fowler 1986, pp. 131, 139 – 143; Piqueray et al. 2013, pp. 189).

Nutritional resources for plant growth and survival are provided by nutrients in suitable soils and available soil water content (Haferkamp 1987, pp. 27 – 30). Seasonal precipitation is the primary source of available soil water in the habitat and the majority of precipitation occurs during the spring, summer, and fall (US Climate Data 2017, entire; Kitchen 2018, p. 1). The species' range receives a considerable amount of summer monsoonal moisture. July and August are the wettest months of the year based on historical records at the Desert Experimental Range (Kitchen 2018, p. 1). Adequate soil moisture supports seed germination in the winter and spring; above-ground growth, flowering, and reproduction in the spring and summer; and root growth in the spring and fall (Haferkamp 1987, pp. 27 – 30; Radville et al. 2016, pp. 9 - 11; Shock et al. 2017, p. 1188).

Flowering generally occurs from June to August. The seeds, which are 0.08 to 0.10 in. (2 to 2.5 mm) long, mature from July through September (Welsh *et al.* 2008, p. 588). We do not have a clear understanding of the species' reproductive biology (breeding system) and the degree it relies on pollinators for reproduction. Without additional species-specific information, we assumed that pollinators are required for maximum reproduction and genetic diversity based on published information for other rare endemic species (Geer *et al.* 1995, p. 20; Tepedino 2000, p. III.5-7; Tepedino 2005, p. 2; Lewinsohn and Tepedino 2007, p. 234). Research on the species' breeding system and pollinators should be prioritized in the future.

A wide variety of non-specialist insects may pollinate the species including bees, wasps, flies, and ants, based on published pollinator information for the *Eriogonum* genera (Archibald *et al.* 2001, p. 612; Tepedino *et al.* 2011, pp. 57, 61, 63 – 65; Larson *et al.* 2014, p. 1027; Tepedino 2015, pers. comm.). The flower-visitors would likely be similar to those of Ostler's peppergrass, and the presence of the two co-flowering species may facilitate pollinator visitation (Geer et al. 1995, pp. 24 – 25; Ghazoul 2006, p. 295, 301 – 303). Long-lived pollinators such as social bee species need a diversity of native plants for foraging throughout the seasons, nesting and egg-laying sites, and undisturbed places for overwintering (Shepherd *et al.* 2003, pp. 49 – 50). Thus, it is important to protect vegetation diversity within and around Frisco buckwheat populations to maintain a diversity of pollinators and support maximum reproduction of individual plants. Collection of additional pollinator-specific information is needed to determine travel distances for Frisco buckwheat pollinators.

We do not know the longevity of the seedbank or the seedbank's contribution to the total population for Frisco buckwheat. Recruitment was observed at all populations in 2010, and seedlings or small juveniles comprised 25 percent of the total plants at the Grampian Hill population (Miller 2010g, p. 4). Based on limited field observations, recruitment may be naturally low or perhaps episodic (Kass 1992a, p. 7; Roth 2010, p. 1).

Frisco buckwheat is associated with the single leaf pinyon-Utah juniper community between 6,200 and 7,228 feet (ft) (1,890 and 2,203 meters (m)) in elevation. Plants are typically found on sparsely vegetated exposed slopes with Ephedra spp. (Mormon tea), *Gutierrezia sarothrae* (snakeweed), *Cercocarpus intricatus* (dwarf mountain-mahogany), and *Petradoria pumila* (rock goldenrod). Associated rare species include Ostler's peppergrass and Frisco clover.

Frisco buckwheat grows on soils derived from Ordovician limestone outcrops (Evenden 1998a, p. 5), and appears to have highly specific soil requirements based on the species' narrow and restricted occupancy. The species occupies only a fraction of the available habitat within approximately 845 acres (ac) (342 hectares (ha)) of Ordovician limestone outcrops in the San Francisco Mountains (Miller 2010a, Appendix F). There is an additional 719 ac (291 ha) of Cambrian dolomite substrates in the San Francisco Mountains where there is the potential for small "islands" of Ordovician limestone outcrops to occur within these substrates (Miller 2010a, Appendix F, p. 7). Field assessments have not been performed in these areas to check for occupancy.

The current hypothesis for the species' narrow distribution within the Ordovician limestone outcrops is that the species may occur at or near contact zones of the limestone and volcanic parent materials where the limestone has turned to marble. Outcrops and soils at these contact zones differ in the chemical composition from the two parent materials and are considered "skarn deposits". Skarn deposits can be associated with mineable resources that include iron, copper, zinc, lead, or gold (Wikipedia 2017, entire). The species may have a narrow tolerance to precipitation and temperature regimes that contribute to its restricted range, but we have no species-specific information about the degree these environmental factors restrict its distribution.

Below is the life stage table for Frisco buckwheat that identifies important life history stages and the timing of those life stages throughout the year based on field observations and the professional opinion of species experts (Table 4).

Table 4. Frisco buckwheat life stage table. Hash-mark cells indicate the likely time period based on professional opinion.

Life Stage	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sept	Oct	Nov	Dec
Seed Germination												
Seedling Establishment												
Flowering & Pollination												
Seed Production												
Seed Dispersal												
Root Growth												

In summary, the resource needs of Frisco buckwheat individuals include:

- Nutrition resources to support plant growth that are provided by:
    - Suitable soils
    - Seasonal precipitation (primarily winter/spring)
- Resources to support plant reproduction that are provided by:
    - Visitation and pollination by pollinators,
    - Floral resources for pollinators provided by the associated plant community, and
    - The presence of Ostler's peppergrass may be important for pollinator visitation
- Habitat characteristics to support the species physiological requirements for germination, growth, and reproduction that are provided by:
    - Suitable soils
    - Suitable microsites for seed germination, establishment, and growth
    - Seasonal precipitation (primarily winter/spring)

2.2.2 *Ostler's peppergrass*

Ostler's peppergrass is a long-lived perennial herb in the mustard family (*Brassicaceae*). Seed germination for the species likely occurs in the spring and is regulated by temperature regime, moisture levels, and light exposure (Tang *et al.* 2010, p. 207). Seeds contain a mucilaginous coat that improves seed germination and adherence to rocks and soil crust, maintains seed viability, may deter herbivory, and restricts seed dispersal (Huang *et al.* 2000, p.48; Tang *et al.*

2010, p. 207; Huang *et al.* 2008, entire). Successful germination and establishment of seedlings depends on the quality and availability of suitable microsites in the habitat (Fowler 1986, pp. 131, 139 – 143; Piqueray *et al.* 2013, pp. 189). Nutritional resources for plant growth and survival are provided by nutrients in suitable soils and available soil water content (Haferkamp 1987, pp. 27 – 30). Seasonal precipitation is the primary source of available soil water in the habitat and the majority of precipitation occurs during the fall, winter, and spring (US Climate Data 2017, entire). Adequate soil moisture in the winter and spring supports seed germination, in the spring and summer supports above-ground growth and reproduction, and in the spring and fall support root growth (Haferkamp 1987, pp. 27 – 30; Radville *et al.* 2016, pp. 9 - 11; Shock *et al.* 2017, p. 1188).

Flowering generally occurs from June to early July, followed by fruit set from July to August (Welsh *et al.* 2008, p. 328). No additional information is available on the life history of Ostler's peppergrass. We do not have a clear understanding of the reproductive biology (breeding system) and the degree it relies on pollinators for reproduction. Research on the breeding system and pollinators should be prioritized for this species. Without additional species-specific information, we assumed that pollinators are required for maximum reproduction and genetic diversity based on published information for another rare endemic *Lepidium* species (Robertson and Ulappa 2004, p. 1707; Billinge and Robertson 2008, pp. 1005 – 1007). A wide variety of non-specialist insects may pollinate Ostler's peppergrass including bees, wasps, and flies (Robertson and Ulappa 2004, p. 1706; Robertson and Leavitt 2011, pp. 384 – 385; Tepedino 2015, *pers. comm.*). The flower-visitors would likely be similar to those of Frisco buckwheat, and the presence of the two co-flowering species may facilitate pollinator visitation (Geer *et al.* 1995, pp. 24 – 25; Ghazoul 2006, p. 295, 301 – 303).

Long-lived pollinators such as social bee species need a diversity of native plants for foraging throughout the seasons, nesting and egg-laying sites, and undisturbed places for overwintering (Shepherd *et al.* 2003, pp. 49 – 50). Thus, it is important to protect vegetation diversity within and around Ostler’s peppergrass populations to maintain a diversity of pollinators and support maximum reproduction of individual plants. Collection of additional pollinator-specific information is needed to determine travel distances for Ostler's peppergrass pollinators.

We do not know the longevity of the seedbank or the seedbank’s contribution to the total population for Ostler's peppergrass. Ostler’s peppergrass is often found growing in the large mounds of Frisco buckwheat individuals. Therefore, Frisco buckwheat may act as a nurse plant that facilitates the establishment of Ostler’s peppergrass seedlings by ameliorating microsite moisture and temperature conditions, as well as possibly serving as a seed trap within the habitat (Badano *et al.* 2016, p. 486, 494 – 496). However, Frisco buckwheat plants may also negatively impact Ostler’s peppergrass by competing for limiting resources such as water and nutrients when plants are larger or affected by harsh climate conditions (O’Brien *et al.* 2017, pp. 6 – 7). These interactions may occur simultaneously, change over time, and depend upon resource availability under various climate and habitat conditions (Armas and Pugnaire 2005, p. 978; Padilla and Pugnaire 2006, p. 196). Research is needed to evaluate the net balance of positive (e.g., facilitation) and negative (e.g., competition) interactions between these two species.

Ostler's peppergrass is associated with the single leaf pinyon-Utah juniper community between 6,200 and 7,228 ft (1,890 and 2,203 m) in elevation. Plants are typically found on sparsely vegetated exposed slopes with *Ephedra spp.* (Mormon tea), *Gutierrezia sarothrae* (snakeweed), *Cercocarpus intricatus* (dwarf mountain-mahogany), and *Petradoria pumila* (rock goldenrod). Associated rare species include Frisco buckwheat and Frisco clover.

Ostler's peppergrass grows on soils derived from Ordovician limestone outcrops (Evenden 1998a, p. 5), and appears to have highly specific soil requirements based on the species' narrow and restricted occupancy. The species occupies a fraction of the available habitat within approximately 845 ac (342 ha) of Ordovician limestone outcrops in the San Francisco Mountains (Miller 2010a, Appendix F). There is an additional 719 ac (291 ha) of Cambrian dolomite substrates in the San Francisco Mountains where there is the potential for small "islands" of Ordovician limestone outcrops to occur within these substrates (Miller 2010a, Appendix F, p. 7). Field assessments have not been performed in these areas to check for occupancy.

The current hypothesis for the species' narrow distribution within the Ordovician limestone outcrops is that the species may occur at or near contact zones of the limestone and volcanic parent materials where the limestone has turned to marble. Outcrops and soils at these contact zones differ in the chemical composition from the two parent materials and are considered "skarn deposits". Skarn deposits can be associated with mineable resources that include iron, copper, zinc, lead, or gold (Wikipedia 2017, entire). The species may have a narrow tolerance to precipitation and temperature regimes that contribute to its restricted range, but we have no species-specific information about the degree these environmental factors restrict its distribution.

Below is the life stage table for Ostler's peppergrass that identifies important life history stages and the timing of those life stages throughout the year based on field observations and the professional opinion of species experts (Table 5).

Table 5. Ostler's peppergrass life stage table. Hash-mark cells indicate the likely time period based on professional opinion.

Life Stage	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sept	Oct	Nov	Dec
Seed Germination												
Seedling Establishment												
Flowering & Pollination												
Seed Production												
Seed Dispersal												
Root Growth												

In summary, the resource needs of Ostler's peppergrass individuals include:

- Nutrition resources to support plant growth that are provided by:
    - Suitable soils
    - Seasonal precipitation (primarily winter/spring)

- Resources to support plant reproduction that are provided by:
    - Visitation and pollination by pollinators
      Floral resources for pollinators provided by the associated plant community
    - The presence of Frisco buckwheat may be important for pollinator visitation

- Habitat characteristics to support the species physiological requirements for germination, growth, and reproduction that are provided by:
    - Suitable soils
    - Suitable microsites for seed germination, establishment, and growth
    - The presence of Frisco buckwheat which may serve as a nurse plant to facilitate plant establishment
    - Seasonal precipitation (winter/spring)

2.2.3 *Frisco clover*

Frisco clover is a dwarf mat-forming or tufted perennial herb in the bean family (Fabaceae). Seed germination for the species likely occurs in the spring after a period of cold, moist stratification over the winter (Van Assche *et al.* 2003, pp. 315, 322). Successful germination and establishment of seedlings depends on the quality and availability of suitable microsites in the habitat (Fowler 1986, pp. 131, 139 – 143; Piqueray *et al.* 2013, pp. 189). Nutritional resources for plant growth and survival are provided by nutrients in suitable soils and available soil water content (Haferkamp 1987, pp. 27 – 30). Seasonal precipitation is the primary source of available soil water in the habitat and the majority of precipitation occurs during the fall, winter, and spring (US Climate Data 2017, entire). Adequate soil moisture in the winter and spring supports seed germination, in the spring and summer supports above-ground growth and reproduction, and in the spring and fall support root growth (Haferkamp 1987, pp. 27 – 30; Radville *et al.* 2016, pp. 9 - 11; Shock *et al.* 2017, p. 1188).

Flowering occurs from late May to June, followed by fruit set in June through July (Welsh *et al*. 2008, p. 486). No other information is available on the life history of Frisco clover. We do not have a clear understanding of the reproductive biology (i.e., breeding system) and the degree it relies on pollinators for reproduction. Research on breeding system and pollinators should be prioritized for this species.

Without additional species-specific information, we assumed that pollinators are required for maximum reproduction and genetic diversity based on published information for other rare endemic species (Geer *et al.* 1995, p. 20; Tepedino 2000, p. III.5-7; Tepedino 2005, p. 2; Lewinsohn and Tepedino 2007, p. 234). Based on the flower shape of Frisco clover, bees are likely the primary pollinators. A wide variety of bees may pollinate the species including bumblebees (*Bombus* sp.), native, solitary bees of the *Osmia* genus, and long tongued bees in the families *Apidae* and *Megachilidae* (Tepedino 2015, *pers. comm*).

Long-lived pollinators such as social bee species generally need a diversity of native plants for foraging throughout the seasons, nesting and egg-laying sites, and undisturbed places for overwintering (Shepherd *et al.* 2003, pp. 49 – 50). Thus, it is important to protect vegetation diversity within and around Frisco clover populations to maintain a diversity of pollinators and support maximum reproduction of individual plants. Collection of additional pollinator-specific information is needed to determine travel distances for Frisco clover pollinators.

We do not know the longevity of the seedbank or the seedbank's contribution to the total population for Frisco clover. In general, species in the bean family have persistent seed banks with at least some proportion of the seed bank being long-lived because the seeds are physically dormant for long periods of time (Orscheg and Enright 2011, p. 186; Segura *et al.* 2014, p. 75). Physically dormant seeds have a seed coat that imposes a physical barrier between water and the embryo, and this type of dormancy provides an ecological advantage by staggering germination over a long period of time, protecting the embryo from microbial attack, and increasing the longevity of seeds within the soil (Fulbright 1987, p. 40). Species with physically dormant seeds typically have seeds germinating over many years, which increases the probability of the species persistence in an unpredictable environment and has been termed a "bet-hedging strategy" (Simons 2009, pp. 1990 - 1991; Williams and Elliott 1960, pp. 740 – 742). This strategy buffers a population against catastrophic losses and negative effects from environmental variation (Tielbörger *et al.* 2014, p. 4). Therefore, Frisco clover may be dormant and not detectable in drought years, but later detected in the same area given favorable precipitation conditions. As a result, multiple years of surveys may be necessary to determine if Frisco clover is present within suitable habitat.

Frisco clover is typically found within the sparsely vegetated pinyon-juniper community between 5,640 and 8,440 ft (1,720–2,573 m) in elevation. Associated species include *Ephedra* spp. (Mormon tea), *Gutierrezia sarothrae* (snakeweed), *Cercocarpus intricatus* (dwarf mountain-mahogany), and *Petradoria pumila* (rock goldenrod). Associated rare species in the southern San Francisco Mountains include Frisco buckwheat and Ostler's peppergrass, which generally grow on the same substrate in similar but more open habitats adjacent to Frisco clover.

Frisco clover tolerates a wider range of substrates than Frisco buckwheat and Ostler's peppergrass. Frisco clover individuals grow on soils derived from volcanic gravels, Ordovician limestone, and dolomite outcrops. Soils are shallow, with gravels, rocks, and boulders on the surface (Kass 1992c, p. 3; Miller 2010a, p. 1). In the southern San Francisco Mountains, where the majority of plants are located, there are 845 ac (342 ha) of Ordovician limestone and 719 ac (291 ha) of dolomite outcrops (Darnall *et al*. 2010, entire). Ordovician limestone is rare within a 50-mile (mi) (80-kilometer (km)) radius of the San Francisco Mountains, but dolomite outcrops are common in the Wah Wah mountain range to the west (Miller 2010b, Appendix F). We have no information on the extent of volcanic gravels in the species range. Nevertheless, the species occupies only a fraction of the available habitat. The species may have a narrow tolerance to precipitation and temperature regimes that contribute to its restricted range, but we have no species-specific information about the degree these environmental factors restrict its distribution.

Below is the life stage table for Frisco clover that identifies important life history stages and the timing of those life stages throughout the year based on field observations and the professional opinion of species experts (Table 6).

Table 6. Frisco clover life stage table. Hash-mark cells indicate the likely time period based on professional opinion.

Life Stage	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sept	Oct	Nov	Dec
Seed Germination												
Seedling Establishment												
Flowering & Pollination												
Seed Production												
Seed Dispersal												
Root Growth												

In summary, the resource needs of Frisco clover individuals include:

- Nutrition resources to support plant growth that are provided by:
    - Suitable soils
    - Seasonal precipitation (primarily winter/spring)

- Resources to support plant reproduction that are provided by:
    - Visitation and pollination by pollinators
    - Floral resources for pollinators provided by the associated plant community

- Habitat characteristics to support the species physiological requirements for germination, growth, and reproduction that are provided by:
    - Suitable soils
    - Suitable microsites for seed germination, establishment, and growth
    - Seasonal precipitation (winter/spring)

Chapter 3. Species and Population Status and Distribution

In this chapter we consider the historical and current distribution of Frisco buckwheat, Ostler's peppergrass, and Frisco clover and discuss the population needs of the three species across their ranges. We first review the historical information on the range, distribution, and population status of the three species. In the population status section (section 3.2), we provide a short description of each plant population. Finally, we review the population needs of the three species to maintain viability and reduce the likelihood of extinction.

3.1 Range and Distribution

3.1.1 *Frisco buckwheat*

Frisco buckwheat is historically and currently known from three populations in the southern San Francisco Mountains in Beaver County, Utah (Figure 4; Kass 1992a, p. 5; Evenden 1998a, p. 5; Miller 2010a, p. 6; Roth 2010, pp. 1–2). We previously reported four populations for Frisco buckwheat, but we combined two populations (Copper Gulch and Indian Queen) into one population (San Francisco) to be consistent with NatureServe population classification criteria (NatureServe 2004, p. 6).

Despite additional searches in the San Francisco Mountains and surrounding ranges (including the Confusion Range, the Mountain Home Range, and the Tunnel Springs Mountains), no other populations are known to occur (Kass 1992a, pp. 4–5; Evenden 1998a, pp. 6–7 (Appendix C); Evenden 1999, pp. 2–3; Miller 2010c, pp. 1, 4; Miller 2010d, pers. comm.; Roth 2010, p. 4; Hildebrand 2013, p. 19; Wellard *et al.* 2017, entire). We recommend additional surveys be conducted in areas identified as suitable habitat based on the model that was recently developed (Appendix E).

The total range of Frisco buckwheat is less than 5 square miles (sq mi) (13 square kilometers (sq km)), and all three populations occur on private lands (Miller 2010a, p. 6; Roth 2010, pp. 1–2). The total area occupied by Frisco buckwheat is 296.5 ac (120 ha) or 35 percent of the available Ordovician limestone outcrops. Each of the three populations occupy relatively small areas ranging between 45 ac (18 ha) and 188 ac (76 ha), with localized high densities of plants (Evenden 1998, Appendix C; Miller 2010a, Appendix B). The three populations of Frisco buckwheat are located on different topographic features (hilltop, side slopes and drainages) within the San Francisco mountain range.

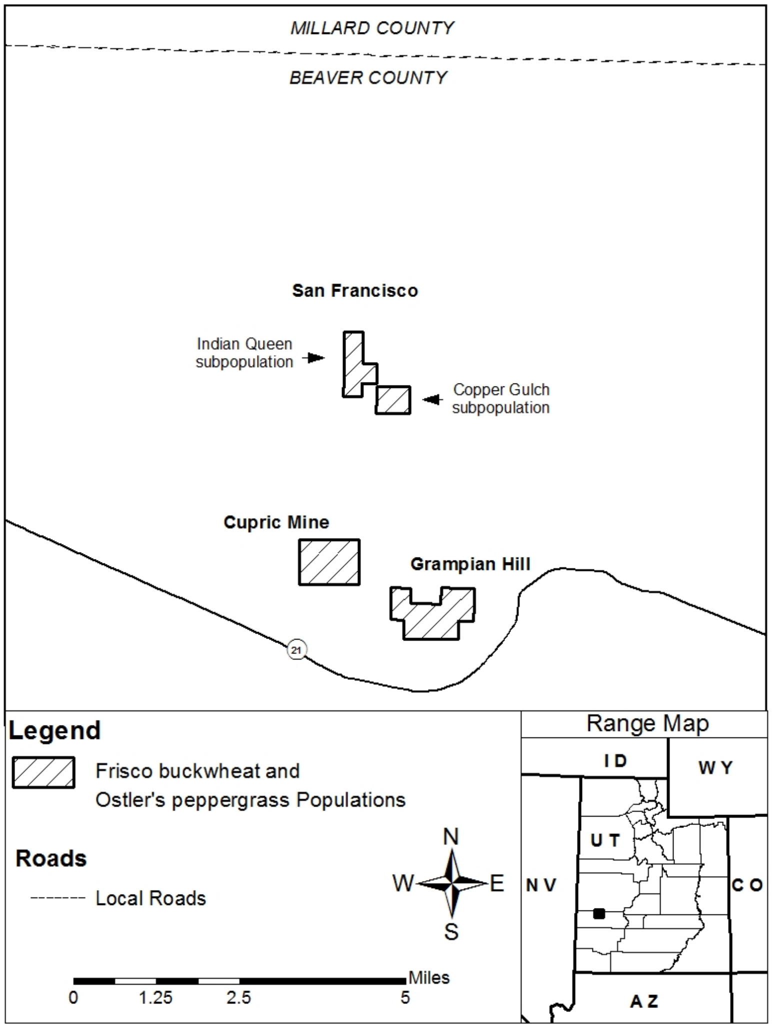

Figure 4. Range and populations of Frisco buckwheat and Ostler's peppergrass.

3.1.2 *Ostler's peppergrass*

Ostler's peppergrass is historically and currently known from three populations in the southern San Francisco Mountains in Beaver County, Utah (Figure 4; Kass 1992b, p. 5; Evenden 1998a, p. 5; Miller 2010a, p. 6; Roth 2010, pp. 1–2; Hildebrand 2013, p. 18). These are the same population areas as reported for Frisco buckwheat (Section 3.1.1, Range and Distribution). We previously reported four populations for Ostler's peppergrass, but we combined two populations (Copper Gulch and Indian Queen) into one population (San Francisco) to be consistent with NatureServe population classification criteria (NatureServe 2004, p. 6).

Despite additional searches in the San Francisco Mountains and surrounding areas (including the Confusion Range, the Mountain Home Range, and the Tunnel Springs Mountains), no other populations are known to occur in these areas (Kass 1992b, pp. 4–5; Evenden 1998a, pp. 6–7, Appendix C; Evenden 1999, pp. 2–3; Miller 2010c, pp. 1, 4; Miller 2010d, pers. comm.; Roth

2010, p. 4; Hildebrand 2013, p. 19; Wellard *et al.* 2017, entire). We recommend additional surveys be conducted in areas identified as suitable habitat based on the model that was recently developed (Appendix E).

The total range of Ostler's peppergrass is less than 5 sq mi (13 sq km), and all three populations of the species occur on private lands (Miller 2010a, p. 6; Roth 2010, pp. 1–2). The total area occupied by Ostler's peppergrass is only 153 ac (62 ha), or just 18 percent, of the available Ordovician limestone outcrops. Populations occupy relatively small areas ranging between 29.5 ac (12 ha) and 84 ac (34 ha) with localized high densities of plants (Evenden 1998a, Appendix C; Miller 2010a, Appendix B). The three populations of Ostler's peppergrass are located on different topographic features (hilltop, side slopes and drainages) within the San Francisco mountain range.

3.1.3 *Frisco clover*

Frisco clover is historically and currently known from six populations on private, Utah School and Institutional Trust Lands Administration (SITLA), Bureau of Land Management (BLM; Cedar City Field Office area), and United States Forest Service (USFS) lands in Beaver and Millard Counties, Utah (Figure 5; Kass 1992c, pp. 4–5; Evenden 1998a, pp. 6–7, Appendix C; Evenden 1999, pp. 2–3; Miller 2010c, pp. 1, 4; Miller 2010d, pers. comm.; Roth 2010, p. 4). We previously reported five populations for Frisco clover. In 2011, a new population of Frisco clover was reported on BLM lands in the Wah Wah Mountains (Kitchen 2015, p. 1 – 2), and was verified in 2016 by UNHP (Wellard *et al.* 2017, pp. 2 – 3). The new population (hereafter referred to as the Wah Wah Mountain population) contains 687 plants in 3 subpopulation areas. The six populations of Frisco clover occur on 296.5 ac (120 ha) of occupied habitat and are distributed across four mountain ranges that encompass approximately 186 sq mi (482 sq km). The six populations of Frisco clover are located on different topographic features (level ground, hilltop, side slopes and drainages) within the four mountain ranges.

Despite additional searches in the San Francisco Mountains and surrounding areas (including the Confusion Range, the Mountain Home Range, and the Tunnel Springs Mountains), no other populations are known to occur in these areas (Kass 1992c, pp. 4–5; Evenden 1998a, pp. 6–7, Appendix C; Evenden 1999, pp. 2–3; Miller 2010c, pp. 1, 4; Miller 2010d, pers. comm.; Roth 2010, p. 4; Hildebrand 2013, p. 19; Wellard *et al.* 2017, entire). We recommend additional surveys be conducted in areas identified as suitable habitat based on the model that was recently developed (Appendix E).

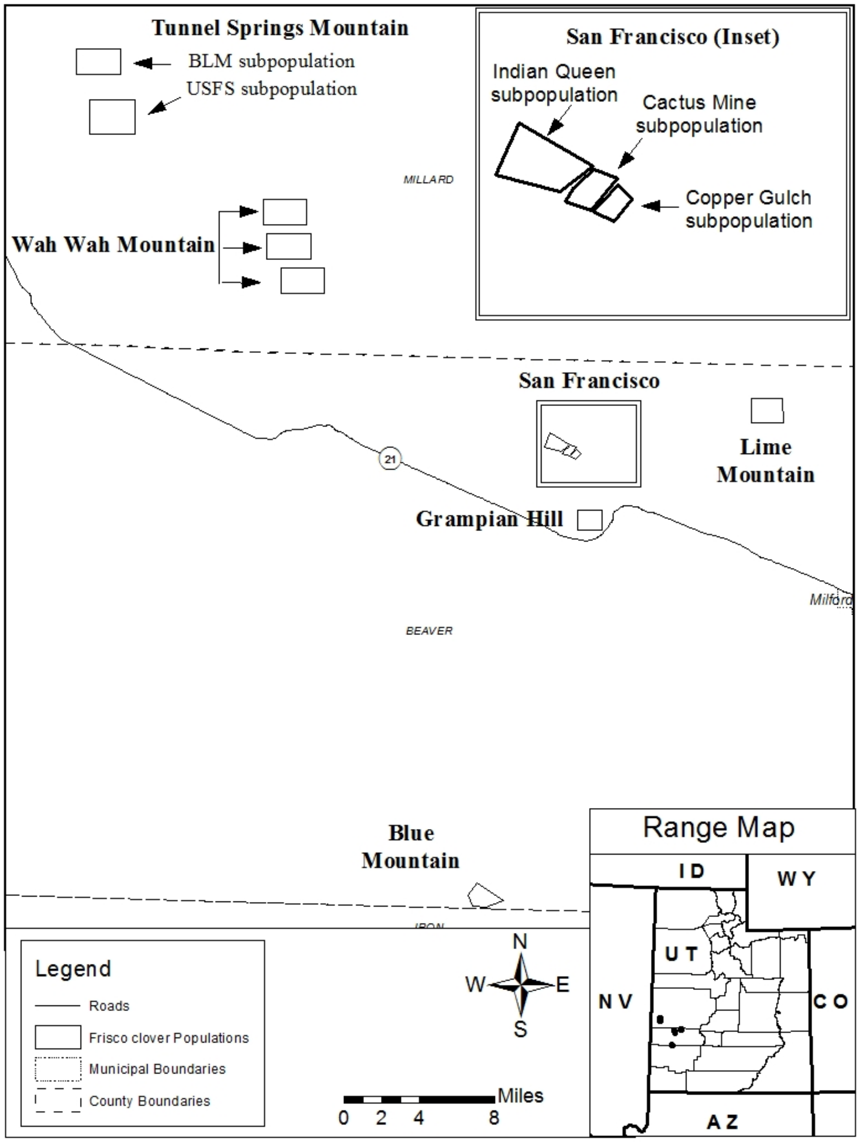

Figure 5. Range and populations of Frisco clover.

3.2 Population Status

3.2.1 *Frisco buckwheat*

The three known Frisco buckwheat populations are located on private lands (Table 7; Miller 2010a, p. 6; Roth 2010, pp. 1–2). The species' presence on private lands hinders our ability to collect accurate long-term population counts or trend information because of access limitations. Populations were visited sporadically over the last couple of decades and population estimates and area of occupied habitat are a compilation of the most recent or comprehensive survey for the species (Table 7; Evenden 1998a, Appendix C; Miller 2010a, entire; Miller 2010c, entire; Roth 2010, entire). The most recent surveys were completed in 2010 and the species was documented at all three known populations (Miller 2010a, entire). As mentioned above, population estimates may be highly subjective in the absence of actual population counts and it is difficult to accurately distinguish individual plants because of their sprawling, mound growth form. For example, the size of the Cupric Mine population may be considerably larger than what we report here and should be confirmed by a census (Wolf 2018, p. 1).

Table 7. Population and occupied habitat area estimates for Frisco buckwheat.

<table>
<tr><th>Population</th><th>Land Ownership</th><th>Survey Year</th><th>Estimated Population Size</th><th>Currently Occupied Habitat Area (ac/ha)</th></tr>
<tr><td>Grampian Hill</td><td>Private</td><td>1998</td><td>20,000</td><td>188 ac/ 76 ha</td></tr>
<tr><td>Cupric Mine</td><td>Private</td><td>2010</td><td>1,000</td><td>45 ac/ 18 ha</td></tr>
<tr><td rowspan="2">San Francisco</td><td>Private (Copper Gulch subpopulation)</td><td>2010</td><td>37,500</td><td>36 ac/ 14.5 ha</td></tr>
<tr><td>Private (Indian Queen subpopulation)</td><td>1992; 2010</td><td>20,000</td><td>27.5 ac/ 11 ha</td></tr>
<tr><td>Totals</td><td></td><td></td><td>78,500*</td><td>296.5 ac/ 120 ha</td></tr>
</table>

Frisco buckwheat occupies an estimated 296.5 ac (120 ha) within its range. The acreage is considerably larger than previously reported 52 ac (21 ha) in our 2011 12-month finding and previous CNORs for the species. This is because we now digitize areas of past survey information from the Utah Natural Heritage Program (UNHP; Evenden 1998b, entire), and include an occupied area estimate of 7.8 ac (3.2 ha) (using a 330 ft (100 m) radius) around plant point locations located outside of delineated occupied habitat polygons for the species. This method provides a better representation of the species' habitat extent based on the incomplete point data set for the species during surveys.

3.2.1.1 Grampian Hill Population

This Frisco buckwheat population contains the largest area of occupied habitat for the species (Table 7). It is located at the southern end of the San Francisco mountain range on private land.

Occupied habitat occurs on sparsely vegetated slopes within the single-leaf pinyon pine (*Pinus monophylla*)-Utah juniper (*Juniperus osteosperma*) plant community (Figure 6). The species grows on multiple aspects, and Ostler's peppergrass plants are found growing within individual plant mounds (Figure 7). Frisco clover is located in adjacent habitat.

Figure 6. Grampian Hill population, NW slope. Photo by Daniela Roth, Service.

Grampian Hill provides the highest quality, intact habitat for Frisco buckwheat and the species occurs in high abundance at this population (Evenden 1998a, p. 4; Table 7). No habitat disturbances were detected in occupied habitat during the last visit to the Grampian Hill population in 2010, and cheatgrass levels were low (Roth 2010, p. 4 , Evenden 1998a, pp. 9 – 10; Miller 2010g, p. 5). Suitable habitat in adjacent BLM lands should be surveyed to locate plants and potential introduction sites since only a small fraction was visited in 2010 (Miller 2010a, p. 1).

Figure 7. Frisco buckwheat and Ostler's peppergrass individuals growing together at Grampian Hill population. Photo by Daniela Roth, Service.

Historical precious metal exploration and mining activity has disturbed some areas adjacent to the Grampian Hill population and may have reduced the historical distribution of the species at these lower elevations. We do not have documentation of the area or percentage of habitat disturbed by past exploration and mining activities. Frisco buckwheat was documented on disturbed areas of old mine excavations (Hildebrand, 2013, p. 44). However, the majority of the occupied habitat appears to be upslope of past precious metal mining activity (Evenden 1998a, p. 4; Miller 2010g, p. 4). The Grampian Hill population is surrounded to the east by old mine shafts associated with the King David Mine, which is part of the historical Horn Silver Mine. The Horn Silver Mine was one of the largest silver mines in the country until it collapsed in 1885 (Murphy 1996, p. 1; Evenden 1998a, p. 3). Exploration activities occurred at the Horn Silver Mine in 2002 (Franconia Minerals Corporation 2002, p. 1) and mining patents were recently leased where this population occurs (Alderan 2017b, p. 9). Cheatgrass (*Bromus tectorum*) is present in adjacent habitat in portions of the lower slopes of Grampian Hill, likely occupying highly disturbed areas from past mining activity (Roth 2010, p. 1).

Stone mining operations do not occur in the immediate vicinity of the Grampian Hill population. There is the potential for stone mining operations to occur in the general vicinity because of the extensive Ordovician limestone outcrops at this location that are readily accessible by existing roads. However, operations would likely occur below the population due to the abundance of limestone deposits at lower elevations on Grampian Hill and the difficult access on steep terrain required to reach the population. As of early September 2017, there is no interest in quarrying limestone deposits in this area based on the lack of permit applications at the Utah Department of Oil, Gas, and Mining (UDOGM) (Brinton 2017b, p. 2).

3.2.1.2 Cupric Mine Population

This Frisco buckwheat population is located at the southern end of the San Francisco mountain range on steep slopes with a northwest aspect (Roth 2010, p. 2). Occupied habitat (Table 7) occurs on sparsely vegetated slopes within the single-leaf pinyon pine-Utah juniper plant community. Ostler's peppergrass also grows at this location in and among Frisco buckwheat individuals.


Figure 8. Gravel mining operation below the Cupric Mine population. Photo by Daniela Roth, Service.

The Cupric Mine area contains intact habitat as well as habitat disturbed by historic copper mining and current stone quarry activity. Frisco buckwheat occurs in moderate abundance at this population (Table 7). The species was documented as actively recolonizing the road bed and areas previously disturbed by historic mining activity (Evenden 1998a, Appendix C). The State UDOGM commented that their staff observed Frisco buckwheat on recently disturbed mining areas at this mine (Utah Governor's Office Public Lands Policy Coordination Office 2018, p. 4). However, this observation should be confirmed by qualified botanists. No recent disturbances were detected in occupied habitat outside of the stone mine permit area during a 2010 visit (Roth 2010, p. 2). Nonnative invasive species' cover is low to non-existent in this population (Roth 2010; p. 2; Red Butte Garden, p. 3). Suitable habitat on adjacent BLM lands was surveyed but no plants were found (Roth 2010; p. 2); however, there is potential for plant introduction sites in these areas.

The Cupric Mine population is located immediately above a mine shaft associated with the Cupric Mine. Historical precious metal exploration and mining activity disturbed some areas adjacent to the Cupric Mine population and may have reduced the historical distribution of the species in this area. We do not have documentation of the area or percentage of habitat disturbed by past exploration and mining activities. Large-scale precious metal exploration and mining in the Cupric Mine ceased decades ago. However, we anticipate mining will occur in the future due to patent rights and recent exploration for silver, zinc, and copper deposits at the nearby Horn Silver Mine (Alderan 2017 and 2017b, entire).

Stone mining occurs within the Cupric Mine population at the Southern White/Mountain Rose stone mine (Figure 8). We previously reported in our CNORs that the active stone mine was located approximately 65.6 ft (20 m) from the population. However, the stone mine has reduced the distribution of the species in this population based on the Evenden polygons that were delineated prior to stone quarry operations (Evenden 1998b, entire). The Southern White/Mountain Rose stone mine was permitted in 1999 and was approved for expansion in 2012 (Brinton 2017a, p. 4). The approved expansion is for an additional 2.5 ac (1 ha) for a total of 7 ac (2.8 ha) of disturbance (Brinton 2015a, p. 1; Brinton 2015b, p. 1). The upper portion of the permitted stone mine operation will result in the loss of approximately 4.3 ac (1.7 ha) of Frisco buckwheat habitat. This acreage is equivalent to 10 percent of the population habitat area (2.4 percent of the species' total population habitat area).

Future expansions of this stone mine are likely (BLM 2012, p. 136). In 2016, the Southern White/Mountain Rose stone mine operator notified the State that they intend to expand the mine and to construct a new road on BLM land to improve access to the existing mine (Brinton 2016, p. 1). However, permitting for these plans has not been submitted to the BLM as of early September 2017 (Ginouves 2017a, p. 2) and no additional expansion plans have been submitted to UDOGM (Brinton 2017b, p. 2).

We do not know how many plants have been and could be lost in this area because project clearance surveys for the plants were not performed. An updated population estimate is needed for areas outside of the permitted mine area.

3.2.1.3 San Francisco Population

This Frisco buckwheat population is the northern-most population of the species in the San Francisco mountain range (Miller 2010a, p. 1). It is comprised of two subpopulations that occur in distinct geographic locations within the population—Copper Gulch and Indian Queen. The San Francisco population is the largest population of Frisco buckwheat and contains 73 percent of the plants in the total population (Table 7). We discuss each subpopulation below.

3.2.1.3.1 *Copper Gulch Subpopulation*

The Copper Gulch subpopulation contains the largest concentration of Frisco buckwheat plants and represents 48 percent of the plants in the total population.

Plants in this subpopulation occur on sparsely vegetated slopes with west and south-southwest aspects where Frisco buckwheat and Ostler's peppergrass are the dominant plant species by canopy cover (Miller 2010c, p. 3). The subpopulation contains intact occupied habitat and habitat disturbed by historical quarry activity (hereafter referred to as the Old Quarry) (Evenden 1998a, p. 5 (Appendix C)). Within the disturbed area of the Old Quarry, Frisco buckwheat has colonized a dirt road and a large extent of the quarry area (Miller 2010c, p. 3; Lewinsohn 2017c, entire). Cheatgrass is present in the habitat but occurs in trace amounts (Miller 2010c, p. 3; Lewinsohn 2017c, entire). The most recent habitat assessment for this subpopulation occurred in 2010.

Historical precious metal exploration and mining for copper occurred near the Copper Gulch subpopulation at the Cactus Mine. This subpopulation is located within 0.3 mi (0.5 km) of old mine shafts associated with the Cactus Mine. There are also a number of existing dirt roads in and around the subpopulation that provide access to historical mine locations. Despite past production from the Cactus Mine of approximately 1.27 million tons (1.40 million standard tons) of recovery grade precious metals, the mine is reported to still contain a similar amount of unrecovered mineral resource (BLM 2012, p. 107). Therefore, we anticipate precious metal exploration and mining to occur in the future in the general location of the Cactus Mine and possibly at the Copper Gulch subpopulation.

In July of 2017, UDOGM received a notice of intention (NOI) to conduct precious metal exploration in the vicinity of the Cactus Mine. Exploration activities associated with a NOI may include the following surface disturbing activities: sinking or drilling of shafts, tunnels, or holes; digging pits; and road building for the purpose of discovering or delineating a mineral deposit. The exploration project area is located approximately 197 ft (60 m) downslope from the Copper Gulch subpopulation, and is not anticipated to directly impact occupied habitat. The UDOGM approval for exploration is valid for two years, and extensions are usually granted if the permit fees are paid.

Stone mining occurred to a limited extent within the Copper Gulch subpopulation based on a delineated 5 ac (2 ha) of disturbance within the habitat. This disturbance acreage is equivalent to 14 percent of the subpopulation area. However, the species has recolonized the disturbance area (Miller 2010c, p. 5; Lewinsohn 2017c, entire). There was no State issued permit for this operation and we do not know when the activity at the Old Quarry took place, but associated activities would have occurred prior to 1998 based on aerial imagery from Google Earth.

There is the potential for stone mining operations to resume at the Old Quarry because of the extensive Ordovician limestone outcrops at this location that are accessible by an existing road. However, the lack of recent activity and more challenging accessibility compared to existing stone mines indicates a low future potential of mining at the Old Quarry (Ginouves 2018c, p. 1). As of early September 2017, there is no interest in quarrying limestone deposits at the Old

Quarry based on the lack of permit applications at UDOGM (Brinton 2017b, p. 2). Stone mining operations at the Old Quarry would not likely occur as part of the active Indian Queen quarry mine due to topographic restrictions that require a separate access location.

3.2.1.3.2 *Indian Queen Subpopulation*

This Frisco buckwheat subpopulation is located on slopes with southern aspects (S, SSW, SSE) (Miller 2010c, p. 5). Occupied habitat occurs on sparsely vegetated slopes within the single-leaf pinyon pine-Utah juniper plant community (Miller 2010a, pp. 1-2). Ostler's peppergrass also grows at this location, and Frisco clover is located in adjacent habitat.

The subpopulation contains intact occupied habitat and habitat disturbed by historical mining activity and recent stone quarry activity (Evenden 1998a, p. 5; Appendix C). Plant density for Frisco buckwheat is highest in areas disturbed by historical precious metal exploration and mining (Evenden 1998a, p. 5 (Appendix C)). Frisco buckwheat colonized a portion of the two track dirt road above the subpopulation (Miller 2010c, p. 5) that may have cut through previously occupied habitat. Exotic species cover is low to non-existent in the subpopulation (Miller 2010c, p. 5; Red Butte Garden, p. 3).

Historical precious metal exploration and mining for copper occurred in and adjacent to the subpopulation at the Cactus Mine. The Indian Queen subpopulation contains two mine shafts in occupied habitat, three additional mine shafts immediately adjacent to occupied habitat, and existing dirt access roads located next to occupied habitat. We do not have documentation of the area or percentage of habitat disturbed by past exploration and mining activities. As mentioned above in the Copper Gulch subpopulation section, a large amount of recoverable mineral resources remain in the deposits associated with the historical Cactus Mine. Therefore, we anticipate precious metal exploration and mining to occur in the future in the general location of the Cactus Mine and possibly at the Indian Queen subpopulation.

Stone mining occurred immediately adjacent to the Indian Queen subpopulation at the Indian Queen stone mine and likely impacted some occupied habitat for the species (Evenden 1998a, p. 5 (Appendix C)). The stone mine occurs partially on BLM land and this was likely the one location where Frisco buckwheat occurred on Federal land but was removed during quarry excavation. We base this assumption on field observations that observed the species upslope, downslope, and around the stone mine (Miller 2010d, p. 1). We estimate the stone mine removed approximately 3.5 ac (1.4 ha) of Frisco buckwheat habitat in the subpopulation. This is equivalent t 13 percent of occupied habitat in the subpopulation and 6 percent of occupied habitat in the population. Quarry activity began in the mid-1990s and ceased around 2006 when the upper portion of the quarry area was reclaimed (Applegate 2006, entire; BLM 2012, p. 115). There is the potential for stone mining operations to occur in the general vicinity because of the extensive Ordovician limestone outcrops at this location that are accessible by an existing road. However, as of early September 2017, there is no interest in quarrying limestone deposits based on the lack of permit applications at UDOGM (Brinton 2017b, p. 2).

3.2.2 Ostler's peppergrass

The three known Ostler's peppergrass populations are located on private lands (Table 8; Miller 2010a, p. 6; Roth 2010, pp. 1–2). The species' presence on private lands hinders our ability to collect accurate long-term population counts or trend information because of access limitations. Populations were visited sporadically over the last couple of decades and population estimates and area of occupied habitat are a compilation of the most recent or comprehensive survey for the species (Table 8; Miller 2010a, entire; Miller 2010c, entire; Roth 2010, entire). The size of the Cupric Mine population may be considerably larger than what we report here and should be confirmed by a census (Wolf 2018, p. 1). The most recent surveys were completed in 2010, and the species was documented at all three known populations (Miller 2010a, entire).

Table 8. Population and occupied habitat area estimates for Ostler's peppergrass.

Population	Land Ownership	Survey Year	Estimated Population Size	Occupied Habitat Area (ac/ha)
Grampian Hill	Private	2010	2,000	84 ac/34 ha
Cupric Mine	Private	2010	1,000	29.5 ac/12 ha current
San Francisco	Private (Copper Gulch subpopulation)	2010	34,000	30.5 ac/12 ha
	Private (Indian Queen subpopulation)	2010	5,000	9 ac/3.5 ha
Totals			**42,000**	**153 ac/ 62 ha**

Ostler's peppergrass occupies an estimated 153 ac (62 ha) within its range. The acreage is considerably larger than the previously reported 52 ac (21 ha) in our 2011 12-month finding and previous CNORs for the species. This is because we now digitize areas of past survey information from the UNHP to be consistent with the survey report (Evenden 1998b, entire), and include an occupied area estimate of 7.8 ac (3.2 ha) (using a 100 m radius) around plant point locations located outside of delineated occupied habitat polygons for the species. This method provides a better representation of the habitat extent based on the survey methods employed. The acreage estimates per population are less than what we report for Frisco buckwheat populations since we did not assume Ostler's peppergrass was always present when only Frisco buckwheat was reported as present in points or polygons. We recommend more refined field surveys for an accurate delineation of occupied habitat for Ostler's peppergrass.

3.2.2.1 Grampian Hill Population

The Ostler's peppergrass Grampian Hill population is in the same location as the Frisco buckwheat Grampian Hill population. Grampian Hill contains the largest area of occupied habitat for the species, and is located at the southern end of the San Francisco mountain range (Table 8). Occupied habitat occurs on sparsely vegetated slopes within the single-leaf pinyon pine-Utah juniper plant community. The species grows on multiple aspects, and is found growing in and among Frisco buckwheat plants and with Frisco clover.

Grampian Hill provides high quality, intact habitat for Ostler's peppergrass and the species occurs in moderate abundance at this population. See the Frisco buckwheat Grampian Hill population description (section 3.2.1.1) for more information on habitat condition, and mining activity in the population area.

3.2.2.2 Cupric Mine Population

The Ostler's peppergrass Cupric Mine population is in the same location as the Frisco buckwheat Cupric Mine population. The Cupric Mine population is located at the southern end of the San Francisco mountain range on steep slopes with a northwest aspect (Roth 2010, p. 2). Occupied habitat (Table 8) occurs on sparsely vegetated slopes with single-leaf pinyon pine and shadscale (*Atriplex confertifolia*) as dominant plant species. Frisco buckwheat also grows at this location.

The Cupric Mine area contains intact habitat as well as habitat disturbed by historical mining and current stone quarry activity. Ostler's peppergrass occurs in moderate abundance at this population. The species was documented as actively recolonizing the road bed and areas previously disturbed by historic mining activity (Evenden 1998a, p. 52 (Appendix C)). The State UDOGM commented that their staff observed Frisco buckwheat on recently disturbed mining areas at this mine (Utah Governor's Office Public Lands Policy Coordination Office 2018, p. 4). However, this observation should be confirmed by qualified botanists. No recent disturbances were detected in occupied habitat outside of the stone mine permit area during the 2010 visit to the Cupric Mine population.

Stone mining occurs within the Cupric Mine population at the Southern White/Mountain Rose stone mine. We previously reported in our CNORs that the active stone mine was located approximately 65.6 ft (20 m) from the population. However, the stone mine has reduced the distribution of the species in this population based on the Evenden polygons that were delineated prior to stone quarry operations (Evenden 1998b, entire). The upper portion of the permitted stone mine operation will result in the loss of approximately 4.3 ac (1.74 ha) of Ostler's peppergrass habitat. This acreage is equivalent to 15 percent of the population area. We do not know how many plants have been and will be destroyed in this area because project clearance surveys were not performed.

See the Frisco buckwheat Cupric Mine population description (section 3.2.1.2) for more information on habitat condition, and mining activity in the vicinity of the population area. An updated population estimate is needed for areas outside of the permitted mine area. Future expansions of this stone mine are likely.

3.2.2.3 San Francisco Population

This Ostler's peppergrass population is the northern-most population of the species in the San Francisco mountain range (Miller 2010a, p. 1). It is comprised of two subpopulations that occur in distinct geographic locations within the population. The San Francisco population is the largest population of Ostler's peppergrass and contains 93 percent of the plants in the total population (Table 8). We discuss each subpopulation below.

3.2.2.3.1 *Copper Gulch Subpopulation*

The Ostler's peppergrass Copper Gulch subpopulation is in the same location as the Frisco buckwheat Copper Gulch subpopulation. The Copper Gulch subpopulation supports high plant abundance and contains 81 percent of Ostler's peppergrass plants in the total population. Occupied habitat occurs on sparsely vegetated slopes with Frisco buckwheat and Ostler's peppergrass as the dominant plant species by canopy cover (Miller 2010c, p. 3). This subpopulation area may contain optimal habitat conditions for the species. In addition to being abundant at this location, these Ostler's peppergrass individuals are the most robust in the species' range (Miller 2010c, p. 3).

The subpopulation contains intact habitat as well as habitat disturbed by historical stone quarry activity. Stone mining appears to have occurred to a limited extent within the Copper Gulch subpopulation based on the delineated 5 ac (2 ha) of disturbance. This disturbance acreage is equivalent to 16 percent of the population area. However, the species has recolonized many portions of the disturbance area (Lewinsohn 2017c, entire).

See the Frisco buckwheat Copper Gulch subpopulation description (section 3.2.1.3.1) for more information on habitat condition and mining activity in the vicinity of the population area.

3.2.2.3.2 *Indian Queen Subpopulation*

The Ostler's peppergrass Indian Queen subpopulation is in the same location as the Frisco buckwheat Indian Queen subpopulation. Occupied habitat occurs on sparsely vegetated slopes within the single-leaf pinyon pine-Utah juniper plant community (Miller 2010a, pp. 1-2). Frisco buckwheat also grows at this location, and Frisco clover is located in adjacent habitat.

The Indian Queen subpopulation contains intact habitat as well as habitat disturbed by historical precious metal mining activity (Evenden 1998, p. 5 (Appendix C)). No recent disturbances were detected in intact, occupied habitat during the 2010 and 2015 visits (Miller 2010c, p. 2; Red Butte Garden 2015, p. 3).

The subpopulation is located approximately 328 ft (100 m) upslope of the Indian Queen stone mine. We do not have reliable historical data to know if the species occurred within the stone mine boundary prior to operations. Our habitat area evaluation does not indicate the stone mine impacted occupied habitat. Therefore, we assumed the species' habitat did not occur within the stone mine boundary for this evaluation.

We do not have documentation of the area or percentage of habitat disturbed by past precious metal exploration and mining activities. See the Frisco buckwheat Indian Queen subpopulation description (section 3.2.1.3.2) for more information on habitat condition and historical precious metal mining activity in the vicinity of the population area.

3.2.3 *Frisco clover*

The total number of Frisco clover individuals was derived from observational estimates (Table 9; Miller 2010a, entire; Miller 2010c, entire; Miller 2010d, entire; Roth 2010, entire) and not actual counts. As previously described, these plants grow in dense mat-forming clusters, making it difficult to determine the number of individuals within a cluster. Because individual plants are difficult to distinguish, we do not believe that the variation in population estimates reflects variation in population sizes, but is rather an artifact of survey effort and methods used. In addition, many of the species' occupied sites occur on private lands where access is restricted, so population counts are estimates.

Accordingly, the available population estimates are highly variable and probably not accurate. During the 1990s, population estimates ranged from 3,500 individuals (Evenden 1998a, Appendix C) to approximately 6,000 individuals (Kass 1992c, p. 8). In 2010, the total number of plants was estimated at roughly 12,675 (Table 9; Miller 2010a, p. 1; Miller 2010e, pers. comm.; Miller 2010c, pp. 1, 4; Roth 2010, p. 4). Because of the uncertainty in the population estimates and the different methods used to survey the populations, we are unable to make accurate assessments regarding the population trend for the species. The most recent Frisco clover surveys were done between 2010 and 2016, and the species was documented at all known populations with an estimated population size of 15,675 plants (Table 9; Miller 2010a, entire; Hildebrand 2013, entire; Wellard *et al.* 2017, entire).

Based on the available information, the largest population is the Grampian Hill population. The population estimate for the Grampian Hill population was previously described as many thousands (Miller 2010e, pers. comm.), and for the purpose of this notice of review, we estimate "many thousands" to be approximately 5,000 individuals to be consistent with our 12-month finding (76 FR 10166).

Table 9. Population and occupied habitat area estimates for Frisco clover.

Population	Land Ownership	Survey Year	Estimated Population Size	Occupied Habitat Area (ac/ha)
Blue Mountain	State	2010	250	8 ac/ 3 ha
Grampian Hill	Private	2010	5,000	97 ac/ 39 ha
San Francisco	BLM (Copper Gulch subpopulation)	2010	1,000	2 ac/ 1 ha
	Private (Cactus Mine subpopulation)	2010/2013	300	4 ac/ 2 ha
	Private, BLM (Indian Queen subpopulation)	2010	3,000	40 ac/ 16 ha
Lime Mountain	BLM	2010, 2012	at least 625	14.5 ac/ 6 ha
Tunnel Springs Mountain	BLM	2010	500	47 ac/ 19 ha
	USFS		2,000	64 ac/ 26 ha
Wah Wah Mountain	BLM	2016	3,000	83.5 ac/ 33.5 ha
Totals			**15,675**	**360 ac/ 146 ha**

3.2.3.1 Blue Mountain Population

The Blue Mountain Frisco clover population is located at the southern end of the Wah Wah mountain range on State land managed by SITLA (Table 9). Soils are derived from the Temple Cap formation which includes limestone, sandstone, and siltstone. Occupied habitat occurs on steep, east-facing slopes that are sparsely vegetated within the single-leaf pinyon pine-Utah juniper plant community (Miller 2010h, p. 5; Roth 2010, p. 2). The Blue Mountain population of the species contains approximately 2 percent of the total population.

The Blue Mountain population contains intact habitat for the species (Miller 2010h, p. 5; Roth 2010, p. 2). Cheatgrass was detected in the habitat during the last field visit, but we do not know the extent of its presence (Roth 2010, p. 2). Surveys on adjacent BLM lands were performed in 2010, but we do not know where they occurred (Roth 2010, p. 2). Comprehensive surveys on State and BLM lands are needed in the general vicinity of this plant population. We recommend surveys in nearby areas identified as suitable habitat based on the model that was recently developed (Appendix E).

We have no information that indicates precious metal exploration and mining activities have occurred or are planned in the vicinity of the Blue Mountain population. Stone mining occurs in the vicinity of the population at the Courgraph stone mine (Evenden 1998a, p. 9; Darnall *et al.* 2010, entire; Roth 2010, p. 4). The stones from this mine are primarily used for landscape boulders as well as for road construction projects and building stone (BLM 2012, p. 79; Brinton 2018a, p. 1). The Courgraph mine is located on SITLA lands downslope and approximately 180 ft (55 m) away from the Blue Mountain population (Lewinsohn 2017a, p. 1). The mine began operating in the mid - 1990's and maintains a current permit (BLM 2012, p. 115). In 2016, a 6 ac (2.4 ha) expansion of the mine was approved by UDOGM (Larsen 2016, entire). This stone mine expansion avoided the plant population by approximately 246 ft (75 m). As of August 2017, mining resulted in the expansion of the existing footprint by approximately 0.5 ac (0.2 ha) to the west and upslope of the existing mine (Lewinsohn 2017a, p. 1). Future expansions of the Courgraph mine are likely based on the economic demand for landscape boulders and the continued need for road gravels in the State of Utah (BLM 2012, p. 136; Brinton 2018a, p. 1).

3.2.3.2 Grampian Hill Population

The Frisco clover Grampian Hill population is in the same location as the Frisco buckwheat and Ostler's peppergrass Grampian Hill populations. Grampian Hill is located at the southern end of the San Francisco mountain range. Occupied habitat occurs on sparsely vegetated slopes within the single-leaf pinyon pine-Utah juniper plant community (Miller 2010h, p. 4). The species grows on multiple aspects, and is found growing with Frisco buckwheat and Ostler's peppergrass.

Grampian Hill currently provides the highest quality habitat for Frisco clover across its range. It is the largest population of the species and contains approximately 32 percent of the total population (Table 9). Historical mining activity occurred mostly downhill from plant habitat (Miller 2010h, p. 6), although "scattered mining adits and associated disturbance" were also noted within the population (Kass 1992c, p. 11; Evenden 1998a, p. 37 (Appendix C)). See the Frisco buckwheat Grampian Hill population description (section 3.2.1.1, Frisco buckwheat) for more information on habitat condition, and mining activity in the population area.

3.2.3.3 San Francisco Population

This Frisco clover population is the northern-most population of the species in the San Francisco mountain range and is in the same location as the Frisco buckwheat and Ostler's peppergrass San Francisco populations (Miller 2010a, p. 1). It is comprised of three subpopulations that occur in distinct geographic locations within the population area. The San Francisco population is relatively large and contains 27 percent of plants in the total Frisco clover population (Table 9). We discuss each subpopulation below.

3.2.3.3.1 Copper Gulch Subpopulation

The Frisco clover Copper Gulch subpopulation is north of the Frisco buckwheat and Ostler's peppergrass Copper Gulch subpopulations by approximately 689 ft (210 m). The subpopulation was discovered in 2010 and is located on BLM lands (Table 9).

The Copper Gulch subpopulation has a small amount of occupied habitat but contains the highest plant density of Frisco clover across its range. Due to the high plant density in this area, it may contain optimal habitat conditions for the species. Occupied habitat occurs on sparsely vegetated slopes within the single-leaf pinyon pine-Utah juniper plant community (Miller 2010h, p. 4). Slopes are moderately-steep west and southwest –facing on dolomite soils. Comprehensive surveys are needed at higher elevations in the general vicinity of this plant population. We recommend surveys in nearby areas identified as suitable habitat based on the model that was recently developed (Appendix E).

The subpopulation contains intact habitat that has not been disturbed by historical mining or stone quarry activity. It is located approximately 1,148 ft (350 m) upslope and to the east of the

Indian Queen stone mine. There does not appear to be the potential for stone mining in the habitat, but there is the risk of slope subsidence associated with downslope stone mining.

3.2.3.3.2 Cactus Mine Subpopulation

The Frisco clover Cactus Mine subpopulation is upslope and along a ridgeline that is immediately adjacent to the Frisco buckwheat and Ostler's peppergrass Indian Queen subpopulations. The subpopulation was discovered in 2010 and is located on private lands (Table 9).

Occupied habitat occurs on sparsely vegetated slopes within the single-leaf pinyon pine-Utah juniper plant community (Miller 2010h, p. 5). Slopes are northwest–facing on limestone soils. Comprehensive surveys are needed at higher elevations in the general vicinity of this plant population. We recommend surveys in nearby areas identified as suitable habitat based on the model that was recently developed (Appendix E).

The Cactus Mine subpopulation contains intact habitat that has not been disturbed by historical mining or stone quarry activity (Miller 2010h, p. 6-7). The habitat is located approximately 984 ft (300 m) upslope of the Indian Queen stone mine. There does not appear to be the potential for stone mining in the habitat, but there is the risk of slope subsidence associated with downslope stone mining.

3.2.3.3.3 Indian Queen Subpopulation

The Frisco clover Indian Queen subpopulation is located in the vicinity of the historical Indian Queen precious metal mine on private lands (Table 9). The Indian Queen subpopulation is located approximately 2,067 ft (630 m) to the west of the Frisco buckwheat and Ostler's peppergrass Indian Queen subpopulations. Occupied habitat occurs on sparsely vegetated ridgelines and ravines in the single-leaf pinyon pine-Utah juniper plant community (Miller 2010h, p. 5). Soils appear to be a mixture of dolomite and other non-limestone soils. Comprehensive surveys are needed at higher elevations in the general vicinity of this plant population. We recommend surveys in nearby areas identified as suitable habitat based on the model that was recently developed (Appendix E).

The subpopulation contains intact habitat near historical mining activity (Evenden 1998a, p. 33 (Appendix C)). Historical precious metal exploration and mining occurred near the subpopulation at the Indian Queen Mine and contained high-grade lead and silver ore (Ginouves 2017a, attachment). The historical mine is located approximately 1,247 ft (380 m) from the delineated habitat area. We do not have delineated disturbance areas within this subpopulation and we have no documentation of Frisco clover recolonizing disturbed soils. Additional field visits to the subpopulation are needed to clarify the extent of past disturbance within the habitat area. No recent disturbances were detected in intact, occupied habitat during the 2010 and 2015 visits (Miller 2010h, pp. 6-7; Red Butte Garden 2015, p. 3). Stone mining has not occurred in the subpopulation area, and the Indian Queen stone mine is located approximately 2,559 ft (780 m) away.

3.2.3.4 Lime Mountain Population

The Lime Mountain population is the easternmost population of Frisco clover. Lime Mountain is in the northern part of the Beaver Lake mountain range (Miller 2010h, p. 5). The population was discovered in 2010 on BLM lands and contains approximately 4 percent of the total Frisco clover population (Table 9).

Occupied habitat occurs on a sparsely vegetated ridgeline in the single-leaf pinyon pine-Utah juniper plant community at lower elevations and in the single-leaf pinyon pine-little-leaf mountain mahogany (*Cercocarpus intricatus*) plant community at higher elevations (Miller 2010h, p. 5). Plants are found on multiple aspects in the population on carbonate soils (Miller 2010h, pp. 5 – 6). Comprehensive surveys on BLM lands are needed in the general vicinity of this plant population. We recommend surveys in nearby areas identified as suitable habitat based on the model that was recently developed (Appendix E).

The Lime Mountain population occurs on intact habitat and habitat disturbed by historical mining activity from the Independence Mine, and access roads of the nearby Copper Mountain Mine (Miller 2010c, p. 1; Miller 2010h, p. 5; Hildebrand 2013, p. 85). The last mining activity at the inactive mines near the population area occurred in the early 1980s (Miller 2010h, pp. 6-7). There was no active mining and no current stressors in the vicinity of the population area during the 2010 and 2012 field visits (Miller 2010c, p. 1; Hildebrand 2013, p. 85).

We do not know the extent the species occupies historically disturbed habitat at the Lime Mountain population; however, Frisco clover was observed to occupy an old two-track dirt access road from the nearby Copper Mountain Mine (Hildebrand 2013, p. 85). Additional field visits to the subpopulation are needed to clarify the extent of past disturbance within the habitat area. There is low potential for future precious metal exploration and mining in or near the population area (Miller 2010h, pp. 7). There is currently one exploration project located approximately 1 mile away (northwest) from the Frisco clover population and is not anticipated to impact the population (Ginouves 2017b, p. 1; Ginouves 2018a, p. 3). Stone mining has not occurred in the vicinity of this population.

3.2.3.5 Tunnel Springs Mountain Population

The Tunnel Springs Mountain population is the western-most population located in the northern part of the mountain range. The population is comprised of two subpopulations that occur in two distinct geographic locations within the population area. The Tunnel Springs Mountain population contains 16 percent of plants in the total Frisco clover population (Table 9). We discuss each subpopulation below.

3.2.3.5.1 USFS Subpopulation

The USFS subpopulation of Frisco clover was discovered in the early 1980's and is located within the Desert Experimental Range (DER) on USFS lands (Table 9; Evenden 1998a, p. 7). The DER was a designated Biosphere Reserve under the United Nations Educational, Scientific, and Cultural Organization (UNESCO) Man and the Biosphere Program between 1976 and 2017 (Kitchen 2018, p. 1). The USFS is responsible for conservation and sustainable land use management within the DER and there are no anticipated land use and management changes in the future (Kitchen 2018, p. 1).

Occupied habitat occurs on slopes and ridges in the single-leaf pinyon pine-Utah juniper plant community (Evenden 1998a, p. 58 (Appendix C)). Plants are found on steep, mostly north-facing slopes. Soils include a mixture of limestone and dolomite.

Historical use in the habitat includes unmanaged, possibly intense, winter and spring sheep grazing between the 1870s and 1930s (Murdoch and Welsh 1971, entire; Kitchen 2018, p. 1). This use likely extended to all populations of Frisco clover during this time period. We have no information on how extensive the impacts were to the species at the time, and there does not appear to be a long-term impact to the habitat based on the current high quality habitat conditions.

Currently, the USFS subpopulation occurs on intact habitat with no documented recent disturbances (Evenden 1998a, p. 57 (Appendix C)). There was no disturbance documented in the vicinity of the population area during the most recent 2016 field visit (Wellard *et al.* 2017, p. 5), and we do not expect precious metal exploration and mining or stone mining to occur within this subpopulation area (Kitchen 2017, p. 1).

3.2.3.5.2 BLM Subpopulation

The BLM subpopulation of Frisco clover was discovered in late 1990's and is located on BLM lands (Evenden 1999, pp. 2 – 3). Occupied habitat occurs on slopes and ridges in the single-leaf pinyon pine-Utah juniper plant community (Roth 2010, p. 3). Plants are highly localized on white outcrops of undocumented origin within a west-facing drainage below a ridgeline.

The BLM subpopulation occurs on intact habitat where livestock grazing is the only documented disturbance (Evenden 1999, pp. 6 – 7; Roth 2010, p. 3). In 1999, an allotment fence was installed within the subpopulation area. We do not have documentation on the level of livestock use within the subpopulation area, but plants and habitat did not appear to be negatively impacted during the 2010 visit (Miller 2010h, p. 7). There is no documented historical or current mining activity within the vicinity of the subpopulation area.

3.2.3.6 Wah Wah Mountain Population

The Wah Wah Mountain population of Frisco clover is located in the northern part of the mountain range on BLM lands. The population likely provides connectivity and supports gene flow between the Tunnel Springs and San Francisco populations of the species. The Wah Wah Mountain population is comprised of three subpopulations that occur in three distinct geographic locations within the population area, approximately 2 km (1.2 mi) apart from each other. The population is moderate in size and contains 19 percent of plants in the total Frisco clover population. We do not discuss each subpopulation separately based on the lack of a mining stressor in the three areas.

Occupied habitat occurs on slopes and ridges in the single-leaf pinyon pine-Utah juniper plant community. Plants are found on limestone soils in crevices in cliffs and boulders as well as talus beds surrounding limestone outcrops (Wellard *et al.* 2017, pp. 2 – 3).

The Wah Wah Mountain population occurs on intact habitat with historic grazing disturbance (Murdoch and Welsh 1971, entire). The only recently documented disturbance in the habitat was the 2011 Grassy Cove fire which impacted a portion of the northern subpopulation. The species' presence in the burn perimeter was not greatly affected by the fire. However, cheatgrass was more abundant in burned habitat than in unburned habitat (Wellard *et al.* 2017, p. 3). Additional field surveys are needed to clarify cheatgrass cover in the habitat, document the potential departure from pre-fire habitat conditions within the burned area, and locate additional occurrences of the species.

3.3 Population Needs

The population needs of Frisco buckwheat, Ostler's peppergrass, and Frisco clover are similar so the general needs we identify in this section apply to all three species. A population level need that applies to only one of the species will be specified as such.

Population-level resiliency requires healthy demographics and sufficient habitat to support a healthy demography. Population resiliency is a function of population size and its population growth rate. The population structure of Frisco buckwheat, Ostler's peppergrass, and Frisco clover is comprised of the number of individuals in a given geographical area, and this includes the individuals present but not discernable in the seedbank.

The size of a population influences population resiliency through the processes of demographic and environmental stochasticity. The number of individuals required to ensure long-term persistence of the population of these three species is unknown. Generally speaking, the larger the population, the higher the likelihood of persistence over time (Fisher and Stöcklin 1997, p. 734 - 735; Hanski 1999, p. 36; Pimm *et al.* 1993, p. 10875; Pimm *et al.* 1998, p. 757 - 777), since small populations are inherently more vulnerable to extirpation due to environmental and demographic stochasticity (Given 1994, pp. 66–67).

Population size also affects population resiliency through genetic health. Small populations have lower levels of genetic diversity (heterozygosity), which reduces the capacity of a population to respond to environmental change and may lead to reduced population fitness, such as longevity and fecundity, and higher extinction risk via inbreeding depression (Barrett and Kohn 1991, pp. 4, 28; Brook *et al.* 2002, p. 10 - 12; Ellstrand and Elam 1993, entire; Newman and Pilson 1997, p. 360; Wilcock and Neiland 2002, p. 275; Matthies *et al.* 2004). Maintaining genetic diversity within populations thus generally requires large effective population size and gene flow within and among populations. Genetic flow for these plant species is provided by pollinators via pollen transfer between individuals and populations.

Population size may also affect population visitation by pollinators and exacerbate size effects to genetic health. Smaller and more isolated populations produce fewer seeds and pollen, and thus attract fewer and a lower diversity of pollinators (Paschke *et al.* 2003, p. 1,258; Lienert 2004, p. 62). Reduced pollinator visitation may increase the extent a population produces seeds without pollinator assistance (autogamy) which also results in inbreeding depression (Barrett and Kohn 1991; Huenneke 1991, pp. 31 - 44). In order to maximize genetic diversity as well as individual seed production, it is important to maintain pollinator populations.

The number of individuals comprising a population is influenced by habitat quality and quantity, specifically for these plant species, the quality and availability of intact, suitable soil substrates. Population resiliency appears to require fairly homogenous habitat conditions that provide the necessary nutritional and reproductive resources throughout the season and year-to-year, despite variations in climatic variables, such as temperature and precipitation. For Frisco buckwheat and Ostler's peppergrass, the habitat conditions of local populations appear to be spatially and geologically homogenous, which increases the likelihood of a synchronous response to regional environmental conditions. The only apparent heterogeneity between and within local populations is aspect and elevation (section 3.2.1, Population Status Frisco buckwheat; section 3.2.2, Population Status Ostler's peppergrass; section 3.2.3, Population Status Frisco clover) which likely influences local environmental conditions such as temperature and soil moisture.

The resiliency of a population is also determined by its long-term growth rate and in order for any population to persist over time; its growth rate (λ) must exceed 1.0. Species that fluctuate greatly with environmental conditions require strong growth rates over time to avoid extirpation (Pimm *et al.* 1998, p. 758, 773). The minimum growth rate needed to sustain Frisco buckwheat, Ostler's peppergrass, or Frisco clover population over time is unknown. However, it does not appear that the populations fluctuate greatly with environmental conditions over short time frames due to the apparent long lifespan of these species (section 2.2.1, Life History Frisco buckwheat; section 2.2.2, Life History Ostler's peppergrass; section 2.2.3, Life History Frisco clover). The low level of heterogeneity in habitat conditions increases the likelihood of synchrony among populations, and may reduce the probability of long-term persistence to certain stressors with a range-wide extent (Hanski 1999, p. 28). In spatially heterogeneous populations, it is unlikely that the entire population will contemporaneously experience the same environmental conditions, thus ensuring that not all population will fail due to unfavorable conditions.

In summary, the significant determinants of population-level resiliency for Frisco buckwheat, Ostler's peppergrass, and Frisco clover are a healthy demography and sufficient quality habitat to support this demography. The demography of Frisco buckwheat, Ostler's peppergrass, and Frisco clover populations is a function of each species population size (the number of individuals and seeds) and population growth rate over time, and these two variables depend on the amount and quality of intact, suitable soil substrates. A precise estimate of the area of habitat required to support a viable population is dependent on the quality of the habitat resource, given each species high local abundance on a range of small, medium, and large habitat areas. Lastly, the very small degree of spatial and habitat heterogeneity across each species population area is important to reduce the chances of all populations failing concurrently due to poor environmental conditions, and thus, is important for long-term persistence.

3.4 Species Needs

As species, Frisco buckwheat, Ostler's peppergrass, and Frisco clover need multiple, resilient, connected populations that display a breadth of ecological and genetic diversity across their ranges. Populations that are connected allow for immigration and emigration across the landscape and ensure gene flow as well as recolonization following extirpation of individual sites or populations (Auffret *et al.* 2017, p. 1 – 3). We do not know the genetic variability of the three plant species, although we assumed some degree of genetic exchange is occurring throughout Frisco buckwheat's and Ostler's peppergrass' range between subpopulations and neighboring populations due to their small range size. For the purposes of our assessment, we assumed some degree of genetic exchange is occurring throughout Frisco clover's range. The primary habitat type utilized by Frisco buckwheat, Ostler's peppergrass, and Frisco clover is the single-leaf pinyon pine-Utah juniper, but can also include the single-leaf pinyon pine-shadscale and single-leaf pinyon pine-little-leaf mountain mahogany plant communities. In order to adapt to changing physical and biological conditions, each species needs to maintain its genetic and ecological diversity (representation) and a certain number and distribution of resilient populations across their range (redundancy).

Chapter 4. Current Conditions: Factors Influencing Viability

In this chapter, we discuss the stressors (external factors) that may influence the 3Rs, and thus the viability, of Frisco buckwheat, Ostler's peppergrass, and Frisco clover. These stressors include precious metal exploration and mining, stone mining, nonnative invasive species, and drought. For each stressor, we include a description, a current qualitative assessment of the magnitude of the stressor (where possible), and a summary of ongoing or potential conservation measures that may lessen associated impacts.

4.1 Precious Metal Exploration and Mining

Potential negative effects of precious metal exploration and mining to all three species include the removal of soil and vegetation within construction and development areas. If soil and vegetation removal occur in plant populations, there is the potential for loss of plants and habitat, habitat degradation and fragmentation, impacts to plant growth and reproduction from fugitive dust generation, reductions in plant vigor and reproductive potential for damaged plants, reductions in seed bank quantity and quality, increasing invasive plant occurrences, and reductions in pollinator populations (Sharifi *et al.* 1997, p. 842; Ferguson *et al*. 1999, p. 2; Brock and Green 2003, pp. 14 – 16; Padgett *et al.* 2007, p. 275; National Research Council (NRS) 1999, pp. 161, 163 – 167). There is also the potential for release or exposure to toxic chemicals and wastes, and increased erosion or slope subsidence due to lower-slope activities.

Areas that are permanently lost to development comprise the greatest impact to the species, and depending upon the extent may result in localized extirpation of a sub-population or extirpation of an entire population. Locations for construction staging, work areas, and ingress and egress areas receive various levels of soil and vegetation disturbance that may be considered temporary if the surface is not permanently altered. However, temporarily disturbed areas contain degraded habitat conditions as a result of vegetation removal, compaction of soil and vegetation, soil disturbance and erosion, increased dust deposition, invasion by nonnative invasive species, and in many cases herbicide use (Brock and Green 2003, pp. 14 – 16). The exposure, intensity, and duration of effects are dependent upon the scope, location, and extraction methods of individual projects.

Historic precious metal exploration and mining operations that occurred in or near plant population areas include mine shafts, adits (horizontal tunnels used to extract ore), prospect pits, overburden deposition areas (tailings), and roads (Kass 1992c, p. 11; Evenden 1998a, p. 3; Roth 2010, p. 2; Ginouves 2015b, entire). The Cactus Mine historical operations include open-pit mining, the Cupric Mine contains adits, and the Horn Silver Mine contains an open pit, shafts and adits (Ege 2005, map on p. 29; Krahulec 2018c, entire). Collectively these features resulted in highly altered habitat conditions but the extent of their impacts within plant habitat was small.

Mineral exploration activities also included exploratory drill holes, drill pads, and access roads. These activities resulted in surface disturbance, increased foot and vehicle traffic, vegetation disturbance, and removal of top soil and overburden. Surface disturbance was extensive and concentrated around the Horn Silver and Cactus Mines historically due to the high productivity of these mines. Future precious metal exploration and mining operations may be similar to historic operations or have the potential for large open pit mining operations depending upon the location and character of the mineral resource.

Metal mining activities occurred historically in the San Francisco mountain range (Evenden 1998a, p. 3), and in section 3.2, Population Status, we describe locations of plant populations relative to precious metal mining activities. Mining for base metals (e.g., zinc, lead, copper) also occurred historically, but we do not distinguish between the two types of metal mining and instead refer to all metal exploration and mining as precious metal exploration and mining.

Areas of historic and current precious metal exploration and mining activities overlap with the entire Frisco buckwheat and Ostler's peppergrass ranges, the Frisco clover Grampian Hill population, and were directly adjacent to the Frisco clover San Francisco (Indian Queen subpopulation) and Lime Mountain populations. The two largest historic precious metal mines are Horn Silver Mine and the Cactus Mine. Horn Silver Mine was one of the largest silver mines in the country until the mine collapsed in 1885 (Murphy 1996, p. 1; Evenden 1998a, p. 3). Mining at Horn Silver continued into the 1960s, with an estimated historical production of approximately 18 million ounces of silver, and 178 thousand tons of lead (Alderan 2018a, p. 5). The Horn Silver Mine is located at the base of Grampian Hill below the Grampian Hill population for all three plant species. The Cactus Mine was the largest producer of gold and copper in the San Francisco mining district (Ege 2005, p. 30). Other historic precious metal mines in or near plant population areas include the Cupric Mine, Indian Queen Mine, and Independence Mine.

The San Francisco mountain range continues to be an important location for precious metal exploration. The San Francisco mineral district is the eighth largest metal district in Utah because of its rank for copper, lead, and zinc production (BLM 2012, pp. 107, 112). While large-scale precious metal mining ceased decades ago in and near plant populations, mineral exploration activities continue to occur. In 1998, the San Francisco range was one of the most active precious metal exploration areas in the state (Bon and Gloyn 1998, pp. 11–12). Periodic mineral resource exploration includes: Horn Silver Mines and other patented claims such as Kennecott Minerals Company in 1998 near the Cactus Mine (Bon and Gloyn 1998, p. 12); Franconia Minerals in 2000 to 2002, and 2006 near the Horn Silver Mine (Bon and Gloyn 2000, p. 14; Franconia Minerals Corporation 2002, p. 1; Bon and Gloyn 2002, pp. 9 – 10; Bon and

Krahulec 2006, p. 16); Western Utah Copper Company (WUCC) in 2001 north of the Cactus Mine (Bon and Gloyn 2001, pp. 12 – 13); and Alderan Corporation with planned exploration in the vicinity of the Cactus Mine, Horn Silver Mine, and Cupric Mine (Alderan 2017a, p. 5). Alderan Corporation recently leased mineral claims that overlap all of the plant populations in the San Francisco mountain range (referred to in this document as the Alderan lease area). Kennecott Utah Copper mining company has recently acquired mineral claims directly east and adjacent to the Alderan lease area (Wheeler 2018, p. 48; Ginouves 2018a, p. 3). We know of one mineral exploration project at Lime Mountain that occurred a decade ago and one exploration project that is currently located approximately 1 mile away (northwest) from the Frisco clover population (Ginouves 2017b, p. 1; Ginouves 2018a, p. 3).

On state and private lands, precious metal exploration and mining operations are state regulated by the UDOGM. Mineral mining is subject to the Utah Mined Land Reclamation Act of 1975, including lands with patented mining claims (Utah Code Title 40, Chapter 8). Utah Mined Land Reclamation Act mandates the preparation of State environmental impact assessments for large mining operations, which are defined as mining operations which create more than 10 ac (4 ha) of surface disturbance in unincorporated areas (Brinton 2015a, p. 1). State environmental impact assessments for large mine permits must perform surveys and address, at a minimum, the potential effects on State and Federally listed species. Mines under the 10 ac (4 ha) disturbance threshold still need to obtain a small mine permit from the State, but there is no requirement for surveys or an environmental assessment (Brinton 2015b, p. 1). All mine permits require reclamation and a site-specific soil salvage and replacement plan to minimize impacts to habitat loss and quality. While not required, direct replacement of salvaged seed bearing soils is encouraged.

In the future, we expect mineral exploration to occur in and near plant populations in the San Francisco mountain range. There is considerable uncertainty regarding the potential for future mining because of the uncertainty associated with future mineral markets and the low success of exploration projects (BLM 2012, p. 12; Krahulec 2018a, attachment). The San Francisco Mining District has a moderate development potential for lead-zinc deposits that may also include gold and silver resources (BLM 2012, pp. 16, 132), and a high development potential for copper (BLM 2012, pp. 14, 129), as compared to other potential mining areas in Utah. The future disturbance area associated with copper exploration, development, and extraction ranges from 490 – 1,980 ac (200 – 800 ha) depending upon the type of mining methods used for extraction (underground or open-pit) (BLM 2012, p. 143). For lead and zinc, the estimated future disturbance is about 250 ac for the San Francisco Mining District (100 ha) (BLM 2012, p. 145).

Areas in the San Francisco Mining District with the highest potential for commercial development in or near the three species plant populations include the Horn Silver Mine at Grampian Hill, the vicinity of the Cactus Mine that contains a large amount of unrecovered mineral resource (BLM 2012, p. 107), and the vicinity of the Imperial Mine, immediately north of Grampian Hill. These two areas are currently being explored for potential future development (Alderan 2017a, p. 5). Exploration plans at the Imperial Mine include deep drill holes to characterize a newly identified underground copper target (also referred to as a prospect, an area of exploration interest to detect a mineral deposit) named Perseverance (Alderan 2018b, entire). Collectively, the mineral deposits and targets occurring within The Frisco mineral system are depicted in Figure 9. The two mineral deposit areas and the Perseverance target are discussed below.

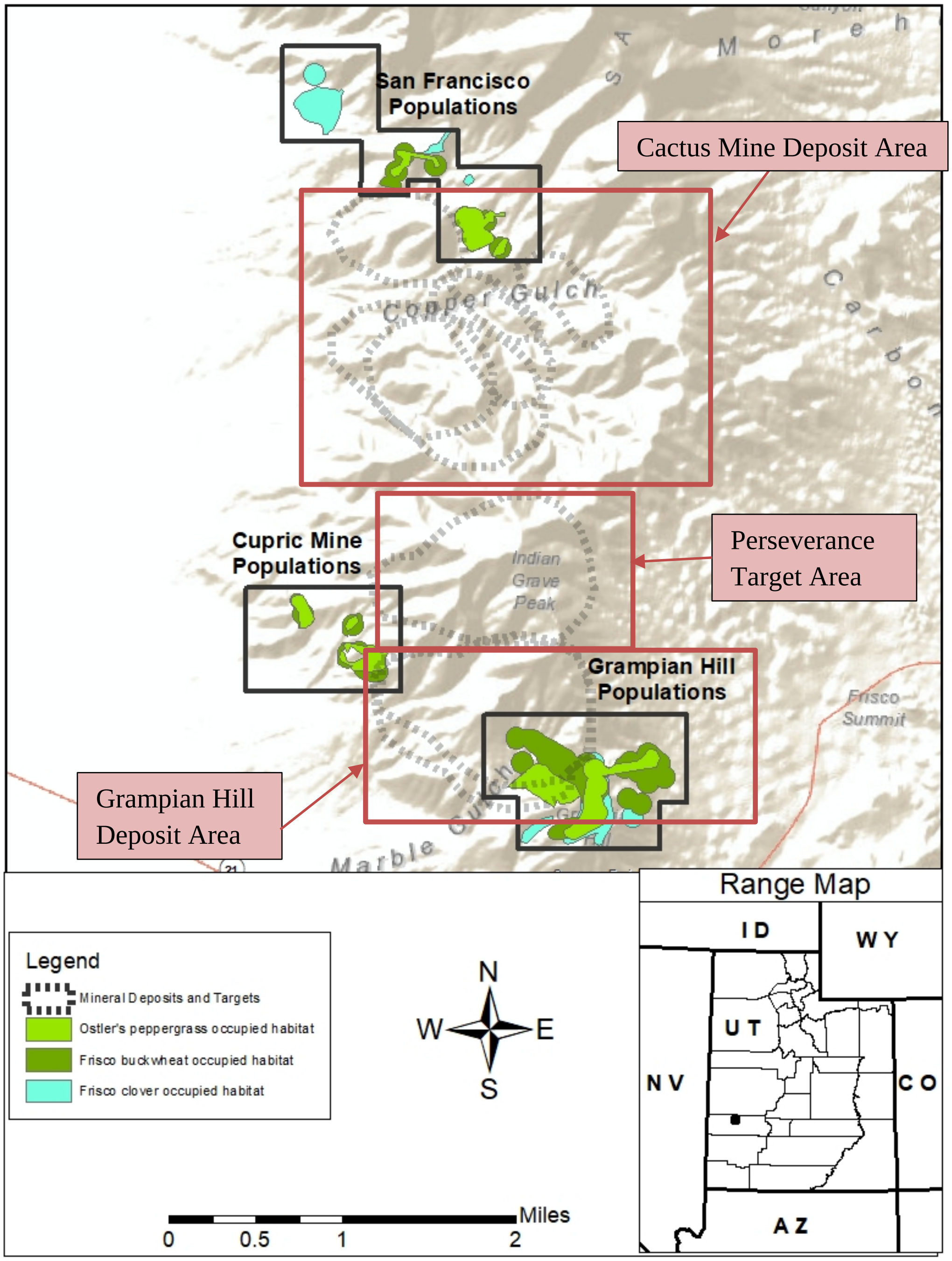

Figure 9. The Frisco mineral system in the San Francisco mountain range. The Cactus Mine deposit area, Grampian Hill deposit area, and the Perseverance target are identified within the red boxes. Mineral deposits and targets are identified by grey hashed outlines. Deposits and targets were sourced from images on Alderan website (Alderan 2017a and 2018a).

The Grampian Hill deposit area includes two mineral targets of commercial interest referred to as the Acrrington Skarn prospect, and abandoned Horn Mine (Alderan 2018c, entire). The Acrrington Skarn prospect area is 2.5 mi (4 km) long by 1.2 mi (2 km) wide and located on private and BLM lands. This prospect overlaps with the three species' Grampian Hill plant populations and to a lesser degree the Cupric Mine populations of Frisco buckwheat and Ostler's peppergrass (Figure 10). The Horn Mine prospect is located on private lands at the location of the historical Horn Silver mine. This prospect is a vertical to very steeply east-dipping deposit that reaches a depth of approximately 951 ft (290 m) and is located vertically below the Grampian Hill plant populations. The two mining prospects within the Grampian Hill area are located on the same topographic feature where the plant populations occur and future mining may pose an increased risk of catastrophic events (subsidence) in plant populations. At this time, there are no plans for exploratory drilling in the Grampian Hill and Cupric Mine plant populations; however, there are plans to improve an existing road within the Grampian Hill population.

The Acrrington Skarn prospect and Horn Mine prospect were historically mined and recently explored. Recent geochemical analyses indicate the presence of copper, gold, lead, zinc and silver mineralization across the Accrington Skarn prospect area, and the presence of zinc mineralization within and adjacent to the historical mine workings of the Horn Mine prospect. The Acrrington Skarn prospect has the potential for a large tonnage deposit of high grade copper-zinc and other metals below where historical mining occurred (Alderan 2018c, pp. 1 – 4). Additional exploratory drilling is needed to evaluate the potential extent of subsurface deposits on this prospect. We do not know the timeframe of the additional exploration of this prospect, but drilling will commence at this prospect in the vicinity of the Imperial Mine in 2018 (denoted as Imperial Claim Area in Figure 10). Not all of the exploration results are publicly available for an independent evaluation of development potential. The Acrrington Skarn prospect and the Horn Mine prospect each have an estimated future mining potential of a 1 in 100 to a 1 in 300 chance (Krahulec 2018a and b, entire).

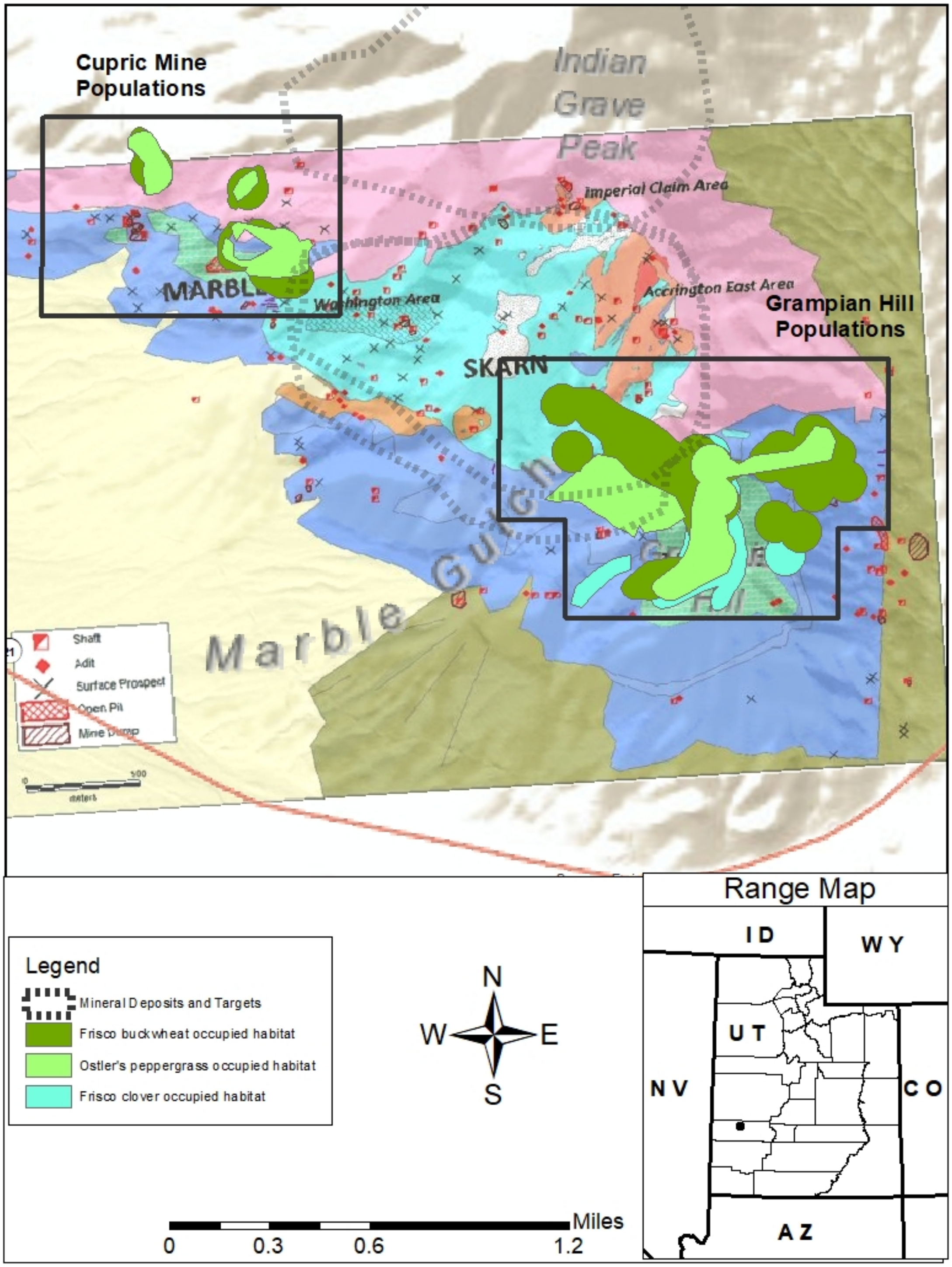

Figure 10. The Acrrington target location and surface geology identified as skarn and marble. The Accrington target location and proximity to the Grampian Hill and Cupric Mine populations of Frisco buckwheat, Ostler's peppergrass, and Frisco clover are depicted here. Surface geology and deposits and targets sourced from the Alderan website (Alderan 2018b).

The Perseverance target area includes one large mineral target of commercial interest for copper mining that was located during the past year of exploration (Alderan 2018b, entire). Initial results indicate a large source of copper deposit that may be similar in size to Utah's Bingham Canyon deposit in Salt Lake County (Figure 11; Alderan 2018b, entire). The Perseverance target area has an estimated future mining potential of a 1 in 500 to a 1 in 1,000 chance because very little information is known about the target at this time (Krahulec 2018a and b, entire). Additional exploratory drilling is planned in 2018 to determine the size and update the mining potential of the Perseverance target. We should have more certainty of the future mining potential of this target within the next year. The Perseverance target does not directly overlap with plant populations. However, the mining potential of this target may strongly influence the future mining potential of the adjacent Grampian Hill and Cactus Mine deposit areas (Figure 9) (Ginouves 2018b, p. 1).

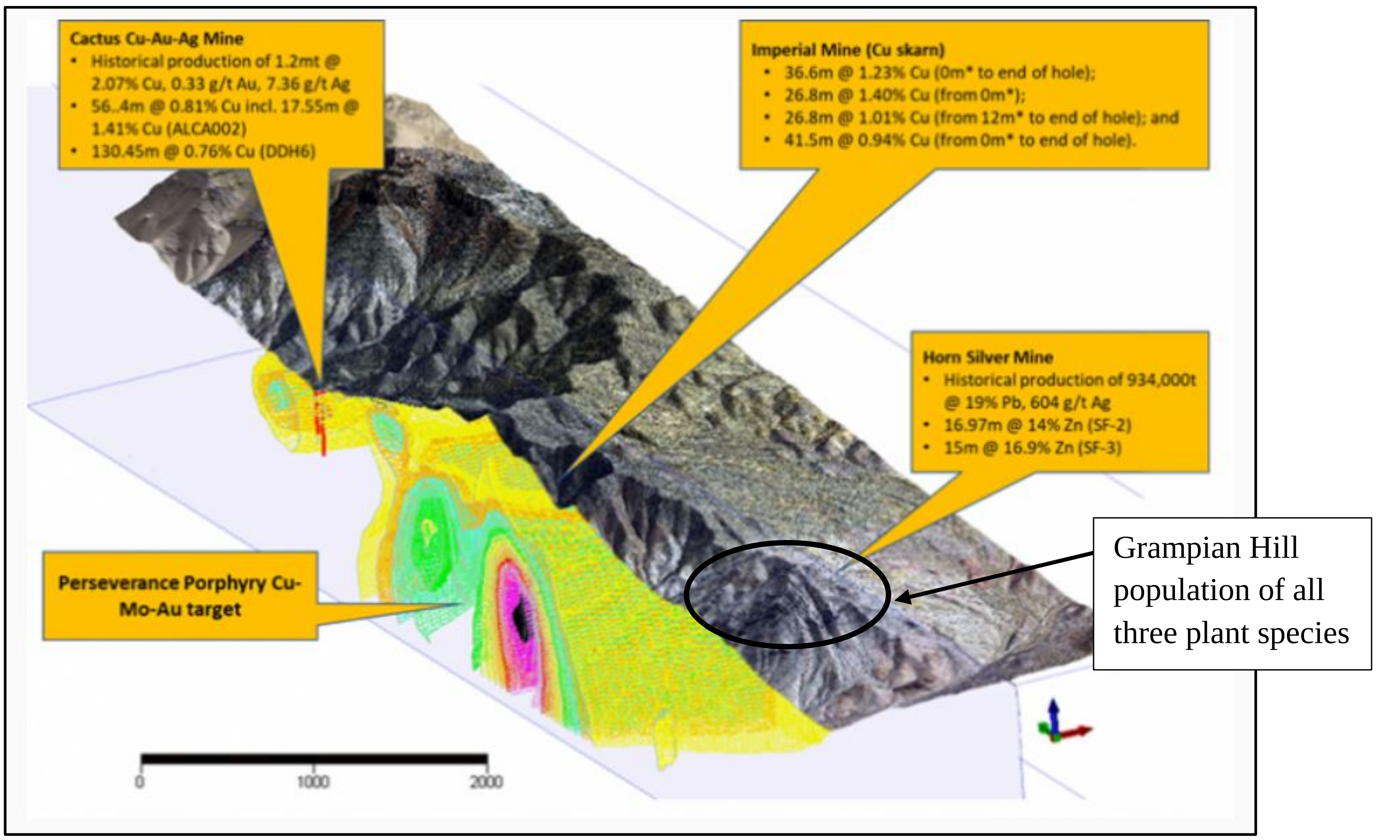

Figure 11. Aerial and cross-sectional view of the Perseverance target location (below ground with pink and black center) and proximity to the other deposit areas within the San Francisco mountain range. Image sourced from Alderan website (Alderan 2018b). The approximate location of the Grampian Hill population for Frisco buckwheat, Ostler's peppergrass, and Frisco clover is hand-drawn over the image.

The Cactus Mine deposit area includes three areas of commercial interest referred to as the Cactus Mine, Bandit, and Wasp targets (Figure 12; Alderan 2018d, entire). Within the past year exploration activities in the Cactus Mine area located the Bandit and Wasp targets that are nearer to the San Francisco populations of Frisco buckwheat and Ostler's peppergrass than the historical Cactus Mine. The San Francisco populations of Frisco buckwheat and Ostler's peppergrass are located approximately 656 ft (200 m) away from the Bandit target (Figure 12). The Cactus Mine deposit area does not directly overlap with plant populations and there are no plans for exploratory drilling in the San Francisco plant populations. The Cactus Mine target has a higher estimated future mining potential (1 in 30 to a 1 in 100 chance) that the Bandit and Wasp targets (1 in 1,000 chance) (Krahulec 2018a and b,entire). At this time, we consider the San Francisco populations for all three species to have a low likelihood of mineral potential. We also consider a low likelihood of the Old Quarry being used as a source of fill material for future mining activities at the Cactus Mine (Ginouves 2018c, p. 1).

Remaining areas appear to have lower potential for commercial development based on the lack of mineral exploration since 2000. In Table 10, we summarize the historic and current precious metal exploration and mining, and the potential for future precious metal exploration and mining by plant species and population.

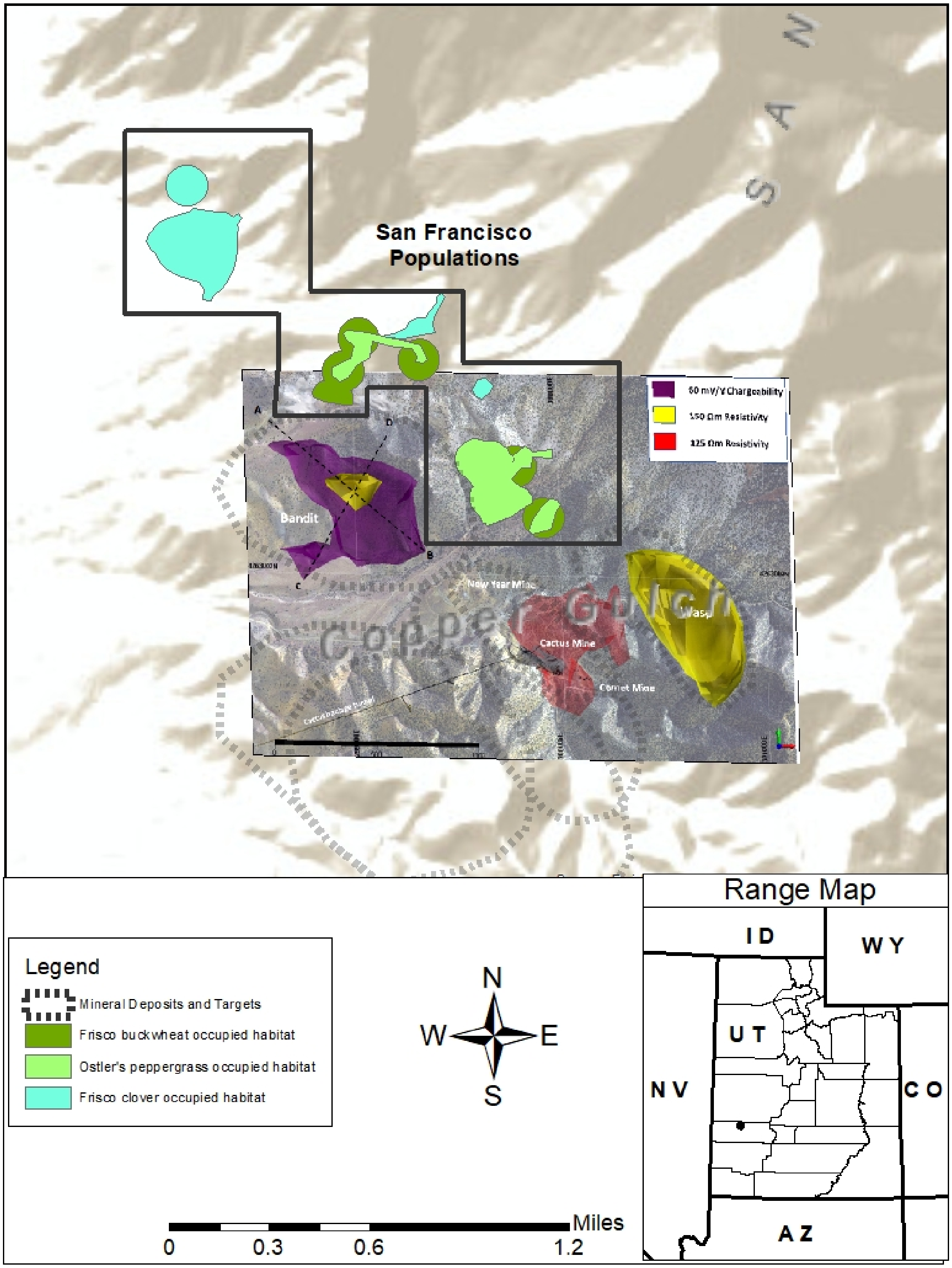

Figure 12. The Cactus Mine, Wasp, and Bandit target locations and proximity to the San Francisco populations of Frisco buckwheat, Ostler's peppergrass, and Frisco clover. Image and target and deposits sourced from the Alderan website (Alderan 2018d).

Table 10. Precious metal exploration and mining activities at Frisco buckwheat, Ostler's peppergrass, and Frisco clover populations.

Species	Population	Subpopulation	Historical Activity	Current Activity	Future Activity
Frisco buckwheat and Ostler's peppergrass	Grampian Hill		silver, lead, copper, zinc (Horn Silver Mine and Imperial Mine)	Mineral exploration planned	silver, lead, copper, zinc (**High Potential: Horn Silver Mine and Imperial Mine**)
	Cupric Mine		silver, lead, copper, zinc (Cupric Mine)	Mineral exploration planned	silver, lead, copper, zinc
	San Francisco	Copper Gulch	silver, lead, copper, zinc (Cactus Mine)	Mineral exploration permitted	silver, lead, copper, zinc (**High Potential: Cactus Mine**)
		Indian Queen	silver, lead, copper, zinc (Indian Queen Mine)	None	silver, lead, copper, zinc
Frisco clover	Blue Mountain		None	None	Not anticipated
	Grampian Hill		silver, lead, copper, zinc (Horn Silver Mine and Imperial Mine)	Mineral exploration planned	silver, lead, copper, zinc (**High Potential: Horn Silver Mine and Imperial Mine**)
	San Francisco	Copper Gulch	None	None	Not anticipated
		Cactus Mine	silver, lead, copper, zinc	None	silver, lead, copper, zinc
		Indian Queen	silver, lead, copper, zinc (Indian Queen Mine)	None	silver, lead, copper, zinc
	Lime Mountain		silver, lead, copper, zinc, native gold, iron (Independence Mine)	Mineral exploration planned	silver, lead, copper, zinc, native gold, iron
	Tunnel Springs Mountains	USFS & BLM	None	None	Not anticipated
	Wah Wah Mountains		None	None	Not anticipated

4.1.1 Impacts to the 3Rs

Precious metals mining-related reductions in habitat quality, habitat quantity, and population size could reduce population resiliency and make the three plant species more vulnerable to stochastic events. Habitat fragmentation can reduce connectivity and restrict or prevent gene flow and dispersal among populations, leading to a reduction in population resiliency and species' redundancy. In general, Frisco buckwheat, Ostler's peppergrass, and Frisco clover plant populations have exhibited high resiliency to historic precious metal exploration and mining when activities occur outside of or adjacent to populations. The data we have indicates Frisco buckwheat and Ostler's peppergrass are resilient to small and localized impacts within their populations where suitable soils remain on the ground surface to allow recolonization. However, based on the restricted range, small total habitat area, and highly specific soil requirements for Frisco buckwheat and Ostler's peppergrass, we anticipate these species will have a low resiliency to impacts that result in larger, population-level changes to population size or habitat area. We do not know how resilient Frisco clover is to small and localized impacts within populations. A careful evaluation of the species' exposure to mining activities, the duration of that exposure (temporary or permanent impact to species' needs), and the intensity of the specific activity is needed to identify individual-, population-, and species-level impacts.

4.1.2 Conservation Measures

4.1.2.1 <u>Existing Conservation Measures</u>

Frisco buckwheat, Ostler's peppergrass, and Frisco clover are BLM sensitive plant species, even though Frisco clover is the only species known to occur on BLM lands. According to the BLM Special Status Species Management Policy Manual #6840, the sensitive species designation affords protection at least comparable to (if not greater than) the treatment of candidates for Federal listing (BLM 2008, p. 43). Specific protections identified for sensitive plant species in the draft BLM Cedar City Resource Management Plan (RMP) include general avoidance of surface disturbance within 330 ft (100 m) of plants or within 660 ft (200 m) unless exceptions are met (BLM 2017, p. 65).

The Frisco clover is not designated as a USFS sensitive plant species. However, as a Federal candidate species, it receives policy-level protection by the USFS through the Sensitive Plants Management Policy # 2670 (USFS 2005, entire). The other two species do not occur on USFS lands and are therefore not provided sensitive species policy protections.

On State and private lands, there are no conservation measures or laws protecting Frisco buckwheat, Ostler's peppergrass, and Frisco clover from precious metal exploration and mining. The State of Utah has implemented the following voluntary conservation measures for these species since 2012:

- In 2012, the UDOGM Abandoned Mine and Reclamation Program voluntarily coordinated with us to survey and implement avoidance and minimization measures for Frisco buckwheat when closing 150 mine openings in the vicinity of the species. Four mine closure locations, all within the Grampian Hill population, were found to contain 500 Frisco buckwheat plants in the vicinity of the mine openings (Transcon Environmental 2012, pp. 7 – 8). Specific conservation measures included: (1) individuals and populations were flagged for avoidance by a qualified botanist; (2) the four mine locations were accessed on foot by work crews; (3) steel gates were used to close the mine rather than back-fill soil adjacent to the mine to minimize soil disturbance in the habitat; (4) vehicle speeds were reduced to 15 miles-per-hour (mph) on access roads adjacent to plant locations to minimize fugitive dust generation; and (5) closure work did not occur during the flowering period to avoid dust impacts to plant reproduction (Transcon Environmental 2012, pp. 8 – 9). The conservation measures successfully avoided impacts to the Frisco buckwheat plants. At this time, there are no plans to complete future mine closures in the San Francisco range where Frisco buckwheat populations occur (Rohrer 2017, p. 1).

- Since 2013, the UDOGM Mineral Mine Permit Program has voluntarily notified operators and new permit applicants about the presence of Frisco buckwheat, Ostler's peppergrass, and Frisco clover populations in the area or vicinity of mine locations. They provide operators with recommendations to avoid impacts to these species and successfully avoided impacts to Frisco clover from the Courgraph stone mine expansion.

- In 2017, the State of Utah funded the development of propagation protocols for Frisco buckwheat and Ostler's peppergrass with the goal of reestablishing plants in populations that experienced historic mining (precious metal and stone) disturbance. Funds were provided by the Endangered Species Mitigation Fund.

4.1.2.2 Recommended Conservation Measures

We recommend the following conservation measures to avoid and minimize impacts to Frisco buckwheat, Ostler's peppergrass, and Frisco clover populations from precious metal exploration and mining:

1. Minimize direct and indirect impacts to plant populations by implementing a 330 ft (100 m) buffer from occupied habitat and a 2.5 percent surface disturbance cap for new disturbance in suitable habitat that occurs within 2 km (1.24 miles) of occupied habitat. This measure is designed to: protect suitable habitat for future population expansion into higher elevations or favorable microsite conditions in the future; maintain the existing seedbank within suitable habitat; support floral resources for plant pollinators; and maintain slope integrity to minimize the risk of subsidence/slumping. The surface disturbance cap should be updated as needed based on new biologically-relevant information such as pollinators, plant population trends, and monitoring of the species' response to nearby disturbance.

2. Minimize direct and indirect impacts to plant populations by controlling the invasion and spread of nonnative invasive species and the generation of fugitive dust during the flowering and growing season using best management practices recommended by our agency. These measures should be implemented during mining and reclamation phases of the project.

3. Perform surveys to locate additional plant populations in suitable habitat prior to mining

activity. Surveys should be conducted by qualified individual(s) and according to Service-accepted survey protocols (Service 2011, entire), and may include the use of drones in inaccessible terrain.

4. Perform periodic monitoring of plant populations where mining is occurring within the population area to document the status and trend of the population and habitat.

5. Develop propagation protocols to establish plants in areas of suitable habitat that require reclamation; in areas of occupied habitat that experienced historic mining disturbance or experience subsidence; and in areas of suitable habitat on Federal lands to provide additional redundancy.

6. Reseed or replant disturbed areas using aerial seeding or hand-planting. Reseed with an appropriate seed mix that excludes the seeding of highly competitive, non-native plant species like crested wheatgrass (*Agropyron cristatum*), highly competitive, rhizomatous plant species like intermediate wheatgrass (*Thinopyrum intermedium*), and non-native fire resistant plant species like forage kochia (*Kochia (= Bassia) prostrata*). Include Frisco buckwheat, Ostler's peppergrass, and Frisco clover into reclamation seeding requirements where appropriate.

7. Secure habitat protection with long-term management agreements, conservation easements, mineral claim lease, land exchange, or fee acquisition in coordination with the land and mineral-claim owner.

8. Implement assisted migration by way of pilot introductions within suitable habitat on protected lands within the San Francisco Mountain range.

9. We identify conservation measures to improve the population condition for individual populations with a mining stressor based on our future condition metrics (Table 25), and future scenarios (section 6, Future Scenarios) in Appendix F

4.2 Stone Mining

The impacts of stone mining are similar to those from precious metal exploration and mining. We would expect an increase in fugitive dust generation from these mines because activities such as blasting, surface excavating, and stone processing may produce large quantities of fugitive dust depending upon the size of the operation. There is also the potential for dust generation to continue at inactive mines if reclamation is not successful (Farmer 1992, p. 66; Padgett *et al.* 2007, p. 275). Fugitive dust accumulation on plants has the potential to impact plant growth and reproduction (Sharifi *et al.* 1997, p. 842; Ferguson *et al.* 1999, p. 2; Lewis *et al.* 2017, p. 430, 436 – 438).

In section 3.2, Population Status, we described locations of plant populations relative to stone mining activities. Stone mining activities occur in the San Francisco mountain range and the southern end of the Wah Wah mountain range at Blue Mountain in areas that overlap with the entire Frisco buckwheat and Ostler's peppergrass ranges, and nearby to the Frisco clover San Francisco and Blue Mountain populations. One historic stone mine, the Old Quarry, is located at the Frisco buckwheat and Ostler's peppergrass Copper Gulch populations. The Old Quarry mine was a small operation based on the shallow excavation within the 5 acre area of disturbance. Excavated white marble at the Old Quarry was likely used for cemetery headstones in the local area (Ginouves 2017a, p. 3). The Old Quarry has not been active in recent times based on our review of publicly available Google Earth aerial imagery from 1998 to the present. Frisco buckwheat and Ostler's peppergrass have recolonized a large extent of this small stone operation (section 3.2.1.3.1, Frisco buckwheat Copper Gulch subpopulation; section 3.2.2.3.1, Ostler's peppergrass Copper Gulch subpopulation).

Currently, there are three stone mines that have been active since 2000 (Appendix D). The two stone mines located in the San Francisco mountain range are the Southern White/Mountain Rose and the Indian Queen. White marble slabs and crushed stone are excavated from the Ordovician limestone deposits at these two mines primarily for use as a landscaping rock and decorative stones (Great American Resources LLC 2017, p. 1). These mines are larger in acreage and have deeper excavations than the historic stone mine (Old Quarry) we discussed in the preceding paragraph. The Southern White/Mountain Rose mine is actively excavating occupied habitat within the Frisco buckwheat and Ostler's peppergrass Cupric Mine populations (section 3.2.1.2, Frisco buckwheat Cupric Mine population; section 3.2.2.2, Ostler's peppergrass Cupric Mine population).

The Indian Queen stone mine excavated occupied Frisco buckwheat habitat in the San Francisco population between 1993 and 2006. Excavation activities ceased in 2006 and the upper portion of the mine was reclaimed between 2006 and 2009. This mine is still considered active because mining activity can resume in reclaimed and un-reclaimed portions of the permitted area at any time. There is no recolonization of Frisco buckwheat in the excavation area. The one active stone mine at Blue Mountain is the Courgraph mine. Limestone is primarily mined for landscaping boulders but also for road construction projects (Larsen 2016, p. 4; Brinton 2018a, p. 1). After a period of inactivity, mining resumed in 2016 under new ownership and with a permit area expansion of 6 ac (2.4 ha) (section 3.2.3.1, Frisco clover Blue Mountain population).

Stone mining operations are State regulated by the UDOGM. Mineral mining is subject to the Utah Mined Land Reclamation Act of 1975, which includes mineral mining on State and private lands, including lands with patented mining claims (Utah Code Title 40, Chapter 8). The regulatory process is similar to permitting for precious metal exploration and mining (section 4.1, Precious Metal Exploration and Mining). Generally, stone quarries are maintained below 10 ac (4 ha) of surface disturbance to avoid large mine status, which requires environmental review during the State permit process (Munson 2010, pers. comm.; Brinton 2015b, p. 1). A mine may stay below this disturbance threshold as long as previously disturbed areas at the quarry site are reclaimed prior to expanding quarrying operations (Munson 2010, pers. comm.). The Southern White/Mountain Rose mine and the Courgraph mine operate under a UDOGM small mine permit and were not required to perform an environmental review (Brinton 2015b, p. 1). The Indian Queen is operating under a UDOGM large mine permit (Brinton 2015b, p. 1), and an environmental assessment was performed in 2001 during the permit application process (Brinton 2015c, attachment).

In the future, we expect stone mine operations will continue at the three active stone mines (Southern White/Mountain Rose, Indian Queen, and Courgraph mines). There is a low likelihood of operations resuming at the Old Quarry in the Copper Gulch population of Frisco buckwheat and Ostler's peppergrass because of the lack of current interest in the area and poorer access compared to the Indian Queen stone mine. The Old Quarry is located near the historic Cactus Mine where there is a high likelihood of future precious metal exploration and mining. However, there is a low likelihood that the Old Quarry will be considered as a source of fill material for future precious metal mining at the Cactus Mine (section 4.1, Precious Metal Exploration and Mining).

The likely continuation and future expansion of stone mining at the three active mines is supported by economic forecasts for an increasing future demand for stone sources in nearby Washington and Iron counties (U.S. Census Bureau 2010 and 2015, entire; Utah Governor's Office of Planning and Budget (GOPB) 2010, p. 48; Utah GOPB 2017, p. 3; BLM 2012, p. 136), and the BLM forecast of a high development potential at existing mines for crushed stone and building stone (BLM 2012, p. 136). In 2008, construction sand and gravel, and crushed stone production ranked as the second most valuable commodity produced among industrial minerals in Utah (Bon and Krahulec 2009, p. 5; Stark 2008, p. 1). After the recession, these commodities continued to increase in value (Boden *et al.* 2016, p. 17).

Sand and gravel, crushed stone, and decorative stone are generally mined for local and regional distribution due to the high cost of transport. The primary market for the landscape boulders mined at the Courgraph Mine is the St. George area in Washington County, Utah (Brinton 2018a, p. 1). In addition to regional distribution, the crushed limestone from the two stone mines in the San Francisco Mountain range is transported to a distribution center for the Home Depot in the nearby town of Milford, where it is packaged and shipped nationwide as landscape rock or decorative stone (Munson 2010, pers. comm.). In Table 11, we summarize the historic and current stone mining operations and the potential for future stone mining by plant species and population.

Table 11. Stone mining activity in Frisco buckwheat, Ostler's peppergrass, and Frisco clover populations.

Species	Population	Subpopulation	Historical Activity	Current Activity	Future Activity
Frisco buckwheat and Ostler's peppergrass	Grampian Hill		None	None	Potential for stone mining below the plant populations
	Cupric Mine		None	Southern White/ Mountain Rose stone mine	Continued expansion of existing stone mine **(High Potential)**
	San Francisco	Copper Gulch	Historical stone mine (unnamed)	None	Potential for stone mining associated with precious metal mining at Cactus Mine
		Indian Queen	None	Indian Queen stone mine	Continued expansion of existing stone mine **(High Potential)**
Frisco clover	Blue Mountain		None	Courgraph stone mine	Continued expansion of existing stone mine **(High Potential)**
	Grampian Hill		None	None	Potential for stone mining below the plant populations
	San Francisco	Copper Gulch	None	None	Not anticipated
		Cactus Mine	None	None	Potential for continued expansion of existing Indian Queen stone mine
		Indian Queen	None	None	Not anticipated
	Lime Mountain		None	None	Not anticipated
	Tunnel Springs Mountains	USFS & BLM	None	None	Not anticipated
	Wah Wah Mountains		None	None	Not anticipated

4.2.1 Impacts to the 3Rs

As mentioned in the summary for precious metal exploration and mining, reductions in habitat quality, habitat quantity and population size could reduce population resiliency and make the three plant species more vulnerable to stochastic events. Habitat fragmentation can reduce connectivity and restrict or prevent gene flow and dispersal among populations, leading to a reduction in population resiliency and species' redundancy. We have one example of Frisco buckwheat and Ostler's peppergrass recolonizing a small, historic stone mine operation at the Old Quarry. Both species exhibited high resiliency to this disturbance and recolonized the entire area of disturbance. However, soil excavation at this mine was not extensive, did not exceed 20 percent of the population area, and suitable soils remained on the surface. Both species appear to be resilient to small and localized stone mine impacts.

Based on the restricted range, small total habitat area, and highly specific soil requirements for Frisco buckwheat and Ostler's peppergrass, we anticipate these species will have a low resiliency to impacts that result in larger, population-level changes to population size or habitat area. Frisco clover has a larger range and less specific soil requirements than the other two plant species. However, we do not have data that indicates the resiliency of Frisco clover to small and localized stone mine impacts within populations. A careful evaluation of the species' exposure to mining activities, the duration of that exposure (temporary or permanent impact to species' needs), and the intensity of the specific activity is needed to identify individual-, population-, and species-level impacts.

4.2.2 Conservation Measures

4.2.2.1 Existing Conservation Measures

On BLM lands, existing conservation measures are the same as discussed for precious metal exploration and mining (section 4.1.2.1, Precious Metal Exploration and Mining). There are no existing or expected future stone mines on USFS lands in the range of these species (Kitchen 2017, entire).

On State and private lands, there are no existing conservation measures or laws protecting Frisco buckwheat, Ostler's peppergrass, and Frisco clover from stone mining. However, the State of Utah has implemented the following voluntary conservation measure for stone mining that would protect or conserve the three plant species:

- Since 2013, the UDOGM Mineral Mine Permit Program has voluntarily notified current operators of mine permits about the presence of Frisco buckwheat, Ostler's peppergrass, and Frisco clover populations in the area or vicinity of the stone mine location. As a result, they successfully coordinated the expansion area of the Courgraph mine to avoid the Frisco clover Blue Mountain population in 2016.

4.2.2.2 Recommended Conservation Measures

Recommended conservation measures are generally the same as discussed for precious metal exploration and mining (section 4.1, Precious Metal Exploration and Mining). We recommend the relocation of existing stone mining operations to areas outside of occupied habitat; the incorporation of avoidance buffers and surface disturbance caps; and reintroduction efforts at the Cupric Mine population for Frisco buckwheat and Ostler's peppergrass, and the San Francisco population for Frisco buckwheat on BLM lands to address impacts to these populations. Additionally, we recommend that fugitive dust control measures be incorporated into mine reclamation plans.

4.3 Nonnative Invasive Species

We previously described the occurrence of nonnative, invasive species in habitats of the populations of the three plant species (section 3.2, Population Status). The spread of nonnative invasive species is considered the second largest threat to imperiled plants in the United States (Wilcove *et al.* 1998, p. 608). Invasive plants—specifically exotic annuals such as cheatgrass (Bromus tectorum)—negatively affect native vegetation, including rare plants. Invasive plants can reduce the abundance of native plants by outcompeting natives for soil nutrients and water (Melgoza *et al.* 1990, pp. 9–10; Aguirre and Johnson 1991, pp. 352–353). Under future climate conditions with elevated levels of carbon dioxide, invasive plants may increase in biomass and seed production and impose stronger competitive effects for soil nutrients and water to Frisco buckwheat, Ostler's peppergrass, and Frisco clover (Mayeux *et al.* 1994, p. 98; Smith *et al.* 2000, pp. 80–81; Ziska *et al.* 2005, p. 1328). Nonnative invasive plants can also completely exclude native plants from their habitat and alter pollinator behaviors (D'Antonio and Vitousek 1992, pp. 74–75; DiTomaso 2000, p. 257; Mooney and Cleland 2001, p. 5449; Levine *et al.* 2003, p. 776; Traveset and Richardson 2006, pp. 211–213).

Cheatgrass is considered the most ubiquitous invasive species in the Intermountain West due to its ability to rapidly invade native dryland ecosystems and out-compete native species (Mack 1981, p. 145; Mack and Pyke, 1983, p. 88; Thill *et al.* 1984, p. 10). One common mechanism for cheatgrass invasion is in response to surface disturbance, so areas exposed to one or more mining stressors are more susceptible to cheatgrass invasion (Hobbs 1989, pp. 389, 393, 395, 398; Rejmanek 1989, pp. 381–383; Hobbs and Huenneke 1992, pp. 324–325, 329, 330; Evans *et al.* 2001, p. 1308). If already present in the vegetative community, cheatgrass typically increases in abundance after a wildfire and has the potential to change fuel properties of the habitat which can alter fire frequency, intensity, extent, type, and seasonality (D'Antonio and Vitousek 1992, pp. 74–75; Brooks and Pyke 2002, p. 5; Grace *et al.* 2002, p. 43; Brooks *et al.* 2003, pp. 4, 13, 15; Menakis *et al.* 2003, pp. 282–283; Brooks *et al.* 2004, p. 677; McKenzie *et al.* 2004, p. 898). Shortened fire return intervals that are associated with cheatgrass invasion make it difficult for native plants to reestablish or compete with invasive plants (D'Antonio and Vitousek 1992, p. 73). The risk of fire is expected to increase from 46 to 100 percent when the cover of cheatgrass increases from 12 to 45 percent or more (Link *et al.* 2006, p. 116). In the absence of exotic species, it is generally estimated that fire return intervals in xeric sagebrush communities range from 100 to 350 years (Baker 2006, p. 181). In some areas of the Great Basin (e.g., Snake River Plain), fire return intervals due to cheatgrass invasion are now between 3 and 5 years (Whisenant 1990, p. 4).

Frisco buckwheat, Ostler's peppergrass, and Frisco clover occur in pinyon-juniper woodlands associated with sagebrush (*Artemisia tridentata* and *A. arbuscula*). However, these species can also occur in more mesic, higher elevations of the Great Basin above the sagebrush-grassland vegetation zone. In pinyon-juniper woodlands, the historical fire return interval can be quite long; in some cases exceeding 400 years (Floyd *et al.* 2004, p. 269). Recent fires in these types of woodlands are mainly the result of the closing of canopy fuels and in some cases cheatgrass invasion, but at present there is not yet evidence to indicate this woodland type experiences an altered wildfire regime (Romme *et al.* 2009, p. 212; Finch *et al.* 2016, p. 172). Thus, we do not expect an increased threat from fire in the three species' population areas.

Historically, Frisco buckwheat, Ostler's peppergrass, and Frisco clover grow in sparsely vegetated communities unlikely to carry fire (section 3.2, Population Status). While we do not have data that provides us with the presence or level of nonnative invasive species in the habitat, we assumed that there were no nonnative invasive species in any plant population historically.

Currently, the primary nonnative invasive species in plant populations for all three species is cheatgrass. However, cheatgrass is present at low to nonexistent levels in all populations of Frisco buckwheat, Ostler's peppergrass, and Frisco clover populations (Table 12). Based on field observations, cheatgrass levels are noticeably higher in recent burned areas compared to unburned habitat (Wellard *et al.* 2017, p. 5, 7; section 3.2.3.6, Wah Wah Mountain population). We do not expect population-level effects to any of the three species from the current low levels of cheatgrass based on best available scientific information.

Table 12. Nonnative Species in in Frisco buckwheat, Ostler's peppergrass, and Frisco clover populations. NA = data not available.

Species	Population	Historical Presence	Current Presence	Future Presence
Frisco buckwheat and Ostler's peppergrass	Grampian Hill	NA Likely none	None in habitat, present downslope in disturbed areas (Roth 2010, p. 2)	Future presence associated with: (1) fire activity in or near the plant population, (2) disturbance from mining activity, and (3) the resistance of the habitat to invasion and spread
	Cupric Mine		Low presence in habitat (<5% cover) (Red Butte Garden 2015, p. 3)	
	San Francisco		Low presence in habitat (<5% cover) (Red Butte Garden 2015, p. 3)	
Frisco clover	Blue Mountain		Present, but no cover estimate (Roth 2010, p. 2)	
	Grampian Hill		None in habitat, present downslope in disturbed areas (Roth 2010, p. 2)	
	San Francisco		NA. Likely trace or low presence. (Miller 2010h, pp. 6-7; Red Butte Garden 2015, p. 3)	
	Lime Mountain		NA Likely trace or low presence (Miller 2010c, p. 1; Hildebrand 2013, p. 85)	
	Tunnel Springs Mountains		None on USFS lands (Kass 1992c, entire; Evenden 1999, entire; Wellard *et al.* 2017, p. 7) Present on BLM lands in adjacent burned habitat (Wellard *et al.* 2017, p. 5, 7)	
	Wah Wah Mountains		Present in habitat, more prevalent in burned habitat (Wellard *et al.* 2017, p. 5, 7)	

In the future, we expect nonnative invasive plant species will continue to occur at low or nonexistent levels unless the habitat is disturbed by stressors such as fire or mining activity. Therefore, we are not concerned about nonnative invasive species increasing on their own but rather that they might act cumulatively with other stressors to exert population-level effects to Frisco buckwheat, Ostler's peppergrass, and Frisco clover. Below, we consider the stressors of fire and mining and the resiliency of the three species' habitat to the invasion and spread of nonnative invasive species in occupied habitat.

We have range-specific information for the three species regarding the historical and current fire regime. Historical fire return intervals in the Wah Wah Mountains varied widely from 24.8 – 100.2 years (Kitchen 2012, p. 58). The current fire return interval is less frequent in the Wah Wah Mountains since Euro-American settlement than the historical fire frequency (Kitchen 2012, p. 64). This is the opposite trend of many areas dominated by sagebrush in the Western United States where fire frequency has increased rather than decreased (Bukowski and Baker, p. 546, 558). This range-specific fire information indicates Frisco buckwheat, Ostler's peppergrass, and Frisco clover may have experienced more frequent fires in the past and that an increase in fire frequency in the future may not negatively impact the species if it returns to a similar historical fire frequency. While fire may not negatively impact the three plant species, the associated increased presence of cheatgrass into recently burned areas is a recent phenomenon and a concern that we identified in our effects summary (Table 12), which has been documented in burned areas next to or directly in two Frisco clover populations.

Habitats of these three species appear to be highly resilient to cheatgrass invasion from past precious metal and recent stone mining disturbance as evidenced by the low levels of occurrence in populations. The poorly-developed soils and higher elevations have likely contributed to the resiliency of the habitat (Masters and Sheley 2001, p. 505). However, as new areas are disturbed, we would expect the presence of cheatgrass to increase since it now occurs in the direct vicinity of all populations (Masters and Sheley 2001, pp. 505 – 506; Novak and Mack 2001, p. 115).

Cheatgrass levels in burned or disturbed habitat may increase to negatively impact growth and reproduction of individual Frisco buckwheat, Ostler's peppergrass, and Frisco clover plants. However, we do not expect the levels of increase that would result in an altered fire regime that would be much shorter than the historical regime. Both the soil type and higher elevation of populations are not consistent with the well-developed soils and lower elevation habitats prone to cheatgrass dominance (Chambers *et al.* 2007, pp. 139 – 140; Chambers *et al.* 2013, p. 366, 370; Davis and Pelsor 2001, p. 421 - 422). In addition, poorly developed soils in other locations have demonstrated high resistant to cheatgrass invasion and thus had a low risk of an altered fire regime (Davies and Hulet 2014, p. 7).

Future cheatgrass levels in burned or mined plant populations are difficult to predict. While it is possible for cheatgrass to spread within Frisco buckwheat, Ostler's peppergrass, and Frisco clover habitat without associated surface disturbance, various environmental factors and ecosystem attributes influence a plant community's resiliency and resistance to cheatgrass invasion (Chambers *et al.* 2013, pp. 365 – 366; Davies and Hulet, 2014, pp. 1 – 2). Thus, a careful analysis of the existing integrity of the three species' habitat and its response to disturbance is needed to assess each community's risk of cheatgrass invasion and dominance (Chambers *et al.* 2013, pp. 365 – 366).

4.3.1 Impacts to the 3Rs

Frisco buckwheat, Ostler's peppergrass, and Frisco clover may experience stronger competitive effects from nonnative invasive species if their presence increases in populations and results in reduced growth, establishment, and reproduction. However, we do not expect nonnative invasive species to increase in populations containing intact habitat or increase in disturbed habitat to levels that alter the fire regime. Impacts to population resiliency from nonnative invasive species are only likely to occur if other stressors such as fire and mining are also present in the habitat and unlikely to be at a level that hinders these species' viability.

4.3.2 Conservation Measures

4.3.2.1 Existing Conservation Measures

The BLM and the State of Utah include nonnative invasive species control and seed mix guidance for reclamation activities associated with mine permitting (Ginouves 2018d, entire; Brinton 2018b, p. 1).

4.3.2.2 Recommended Conservation Measures

The potential invasion of cheatgrass into habitat of these three plant populations is unlikely to be at a level that hinders the species' viability due to soil conditions and higher elevations not normally conducive to cheatgrass invasion. However, the need for nonnative invasive species control should continue to be evaluated and implemented as needed to ensure continued habitat maintenance. We recommend the following conservation measures to avoid and minimize impacts to Frisco buckwheat, Ostler's peppergrass, and Frisco clover populations from nonnative invasive species:

1. Minimize direct and indirect impacts to plant populations to control the invasion and spread of nonnative invasive species as a result of surface disturbance.

2. Incorporate best management practices recommended by our agency to control nonnative invasive species invasion. These practices include:

    a. Reduce the size of surface disturbance and vegetation clearing to the minimum amount needed for construction;
    b. Use existing roads where possible; using existing roads as staging areas;
    c. Reseed areas post-activity with measures outlined for precious metal exploration and mining (section 4.1.2.2, Precious Metal Exploration and Mining);
    d. Perform nonnative invasive species monitoring and control for 2 – 3 years post-surface disturbance.
    e. Coordination with the Utah Field Office is recommended to incorporate the latest guidance for herbicide treatment within sensitive species habitat.

4.4 Drought

Drought is defined as a deficit of precipitation over an extended period, which reduces water supply, water quality, and range productivity, and impacts social and economic activities (Woodhouse and Peck 1998, p. 2693; National Weather Service 2012, p. 1). Drought is recognized as a normal process that is the result of natural climate variability. The southwestern United States experienced the driest period in several centuries between 2000 and 2010 (Cayan *et al.* 2010; Finch *et al.* 2016, p. 159). The result is widespread mortality of trees in pinyon – juniper woodlands throughout the region (Finch *et al.* 2016, p. 172). Since 2000, drought conditions within the three species' range do not appear to be as severe compared to some other areas of the state. Although highly variable from year to year, long-term trends in total annual precipitation have remained essentially unchanged over the last 82 years (Kitchen 2018, p. 3).

Due to the lack of consistent population monitoring (section 3.2, Population Status), we do not have a clear understanding of how Frisco buckwheat, Ostler's peppergrass, and Frisco clover respond to precipitation changes and periods of drought conditions. Since these three plant species grow in drought-stressed landscapes, we would expect them to be drought-adapted provided the severity and duration of the drought does not exceed historical levels (Tielbörger *et al.* 2014, p. 7). Reconstruction of historical climate conditions indicate drought conditions since the early 1900s may not be as severe or long lasting as those experienced within the previous 10,000 years (Mensing *et al.* 2013, pp. 266, 277; Finch *et al.* 2016, p. 162). This suggests recent drought conditions have not exceeded historical levels.

Drought-adapted plant species may experience lower mortality during severe droughts (Gitlin *et al.* 2006, pp. 1477, 1484). Nevertheless, we would expect drought conditions to lead to declines in seedling recruitment and survival, adult plant survival, plant vigor, and reproductive output, which have been documented for other rare plants in the Southwest during drought years (Anderton 2002, p. 1; Clark and Clark 2007, pp. 6–8; Hughes 2005, entire; Roth 2008a, entire; Roth 2008b, pp. 3–4; Van Buren and Harper 2002, p. 3; Van Buren and Harper 2003, p. 240). Large declines have also been reported for common plant species that include short-lived and long-lived perennial plants in response to extreme drought conditions (Miriti *et al.* 2007, p. 35).

4.4.1 Impacts to the 3Rs

Drought reduces plant survival, reproduction, and recruitment rates. This makes populations smaller and less resilient to other stochastic events. The effect of drought may be amplified if it occurs in cumulatively with other stressors such as mining and nonnative invasive species. The relatively localized distribution of Frisco buckwheat, Ostler's peppergrass, and Frisco clover may make these species more susceptible to landscape-level stochastic extinction events. Despite these potential vulnerabilities, all three species appear well-adapted to a dry climate as evidenced by relatively high population abundance since 2000. Frisco buckwheat, Ostler's peppergrass, and Frisco clover likely experienced multiple periods of prolonged drought conditions in the past as documented from reconstructed pollen records in sagebrush steppe lands (Mensing *et al.* 2007, pp. 8–10).

4.4.2 Conservation Measures

4.4.2.1 Existing Conservation Measures

We are not aware of any ongoing conservation measures involving Frisco buckwheat, Ostler's peppergrass, and Frisco clover and drought.

4.4.2.2 Recommended Conservation Measures

Ensuring that plant populations are in high condition will likely buffer the loss of individuals due to drought. Intact habitat conditions would also minimize an exacerbated effect from vegetative competition for moisture by nonnative invasive species. We recommend the implementation of conservation measures for precious metal exploration and mining and stone mining (section 4.1.2.2, Precious Metal Exploration and Mining; section 4.2.2.2, Stone Mining) to help reduce habitat fragmentation and the effects of drought.

4.5 Stressors Considered but not Carried Forward

We considered the potential impacts from livestock use, disease, collection, and wildfire. However, the best available information indicates that these are low level stressors and do not impact these three plant species either by themselves, or cumulatively with any other stressors (Lewinsohn 2018, entire). Therefore, these topics were considered but not carried forward in our evaluation.

Chapter 5. Species Historical and Current Condition

Using the SSA framework, we now describe each species' viability by characterizing the current condition of each species in terms of its resiliency, redundancy, and representation (the 3Rs). In Chapters 6 and 7, we characterize the projected future levels of the 3Rs, respectively and describe each species' level of viability over time.

5.1 Species Resiliency: Historical and Current Condition

For Frisco buckwheat, Ostler's peppergrass, and Frisco clover to maintain viability, their populations, or some portion of their populations, must be resilient; i.e., able to sustain populations in the face of environmental variation (section 1.2, Analytical Framework). Generally speaking, a greater number of healthy populations and spatial heterogeneity occupied by the species increases the likelihood of sustaining populations through time.

Habitat factors play an important role in supporting the resource needs of individual plants and populations. At the population level, we consider the habitat factors that influence the growth rate and size of plant populations to be important. Habitat factors that support maximum population size and habitat occupancy increase the resiliency of a population to stochastic events. Important habitat factors for all three species include: (1) intact suitable soil substrate to maximize recruitment and survival within the population (soil and microsite quality); (2) sufficient floral resources to ensure pollinator visitation and maximize adult reproductive output; (3) suitable climate conditions (temperature, moisture) within species' physiological tolerances to maximize population growth and size; and (4) sufficient seed dispersal and contribution to the seed bank to support population stability or growth (Figure 13). If these habitat factors occur over a sufficiently large area to support a large population size and demographic needs of the species, we anticipate plant populations will be resilient to natural stochastic events.

Resilient Frisco buckwheat, Ostler's peppergrass, and Frisco clover populations occupy habitats of sufficient size to sustain reproducing populations. We have limited information regarding population demographics; though Frisco buckwheat and Ostler's peppergrass can be locally quite abundant as illustrated by individual population sizes (Table 7 and Table 8). We would expect that that survival of seedlings and adult (reproductive) plants, high reproductive output, and a large seedbank would be important to maximize the growth rate and size of populations for all three species as outlined in the species' conceptual model (Third column in Figure 13).

Lastly, resiliency is also influenced by the degree of connectivity among populations. Movement among populations is essential for genetic health via gene flow and demographic rescue. Thus, connectivity among local plant populations is also a requisite for species level resiliency.

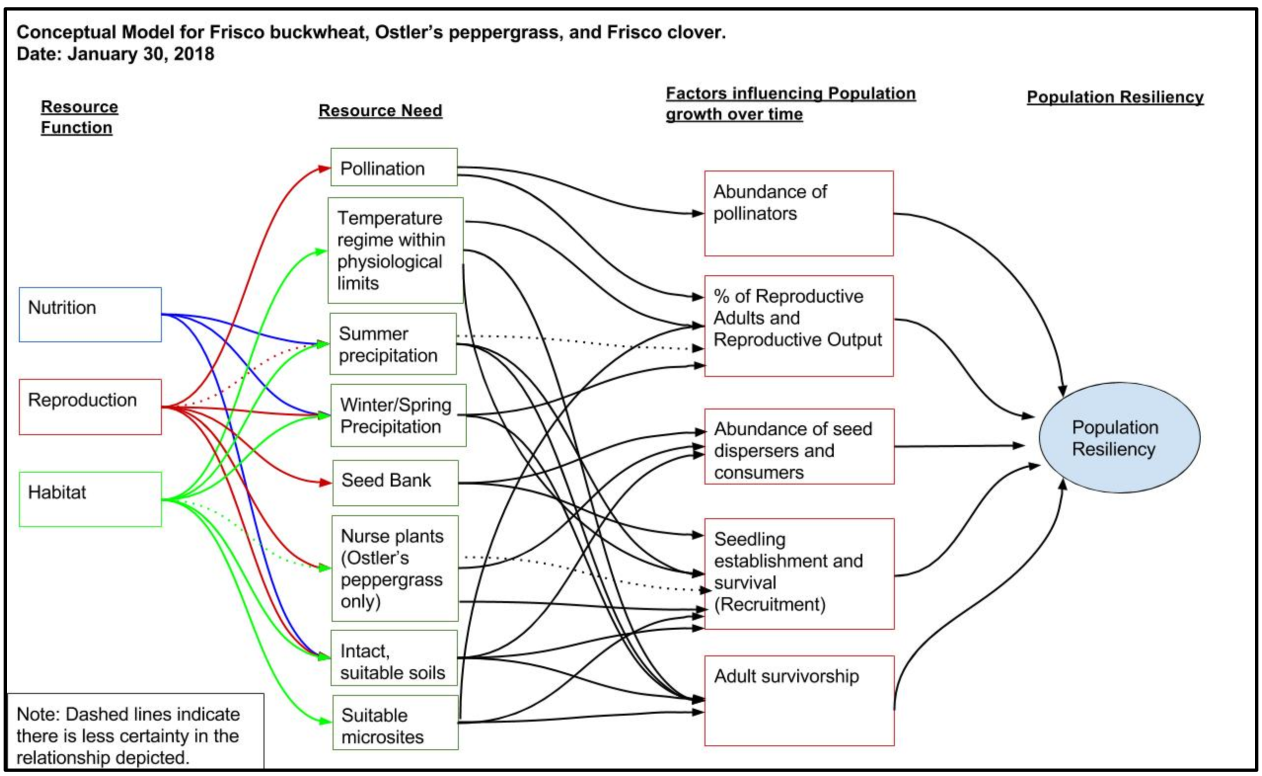

Figure 13. Conceptual Model for Frisco buckwheat, Ostler's peppergrass, and Frisco clover.

5.1.1 *Frisco buckwheat*

The significant determinants of resiliency for Frisco buckwheat are the number of healthy populations, the size of the population, the quality and quantity of the habitat factors to support the species, and the degree of connectivity between populations.

We considered the important resiliency factors for Frisco buckwheat's historical and current condition (Table 13). The current number of Frisco buckwheat populations is the same as the historical number of populations. Because we do not have population or species' abundance estimates prior to 1998 and have no reliable information on population trend, we cannot make comparisons between historical and current population condition using abundance or trend.

The current habitat area is less than the historical habitat area, and the information we have indicates portions of the habitat in the Cupric Mine and San Francisco populations were impacted by historic road and mining development and thus lost to stone mine operations. This is the only difference between the historical and current condition for the species. We have no information that indicates a reduction in connectivity among populations has occurred due to habitat loss.

Table 13. Summary of Resiliency factors for Frisco buckwheat.

Resiliency Factors	Historical Condition	Current Condition	Resultant Change Over Time
Number of Populations	3	3	No change
Population Size	Unknown	78,500	Unknown
Habitat Area	Approximately 297 ac (120 ha)	289 ac (117 ha)	8 ac (3.2 ha)
Habitat Quality	High	High	No change
Population Connectivity	Spatial dispersion of historical populations	Same as historical	No change

The type of stressors affecting Frisco buckwheat has changed over time. Precious metal mining at a commercial scale occurred in or near plant populations in the San Francisco mountain range between 1870 to 1957 (Ege 2005, pp. 29 – 30). The magnitude of this stressor is less today than during the commercial production period because there are now lower levels of precious metal exploration activity. Stone mining began in the early 1990's and continues today. The magnitude of this stressor has increased with the two active stone mines (Southern White/Mt. Rose and Indian Queen mines; section 3.2.1.2, Population Status Cupric Mine population; section 3.2.1.3.2, Population Status Indian Queen subpopulation) in the species' populations. Nonnative invasive species is a new stressor that is now present at low levels in many plant populations.

Frisco buckwheat appears to have some level of tolerance to stressors that result in soil or habitat disturbance. In the San Francisco population, the species occurs in habitat that coincides with areas that experienced concentrated precious metal mining activity or minor quarry activity in the past. The species recolonized portions of existing dirt roads, historic precious metal mining areas, and a historic quarry area in the Copper Gulch subpopulation of the San Francisco population (section 3.2.1.3.1; Evenden 1998a, pp. 4, 5, 10; Miller 2010c, p. 4 – 5; Miller 2010e, p. 1; Miller 2010g, p. 4). This information indicates the species is able to tolerate some soil and habitat disturbance in instances where disturbance is localized and suitable soils remain on the ground surface. Disturbance areas the species recolonized did not exceed 20 percent of a population or subpopulation area. Based on the limited information we have that includes the estimated age of the disturbances (50+ years) and the localized areas where the species has recolonized during that time period, recolonization rates may be slow without the implementation of additional habitat or soil restoration measures. Based on available information, we assumed Frisco buckwheat is not tolerant of large quarry operations that result in deep excavations and more extensive impacts to population and subpopulations. We assumed that the species will slowly recolonize excavation areas to maximize habitat occupancy if: (1) a suitable soil layer (not bedrock) remains on the surface following operations; (2) there is sufficient occupied habitat in the surrounding or adjacent area to provide a genetically diverse seed source for recolonization; and (3) nonnative invasive species establishment in the excavation area is low and does not result in strong vegetative competition.

5.1.2 *Ostler's peppergrass*

The significant determinants of resiliency for Ostler's peppergrass are the same as those identified for Frisco buckwheat: the number of healthy populations, the size of each population, the quality and quantity of the habitat factors to support the species, and the degree of connectivity between populations.

We considered the important resiliency factors for Ostler's peppergrass's historical and current condition (Table 14). The current number of Ostler's peppergrass populations is the same as the historical number of populations. Because we did not have population or species' abundance estimates prior to 1998 and have no reliable information on population trend, we cannot make comparisons between historical and current population condition using abundance or trend to past conditions.

The current habitat area is less than the historical habitat area; the information we have indicates a portion of the habitat in the Cupric Mine population has been lost to stone mine operations. This is the only difference between the historical and current condition of the species. We have no information that indicates a reduction in connectivity among populations has occurred due to habitat loss.

Table 14. Summary of Resiliency factors for Ostler's peppergrass.

Resiliency Factors	Historical Condition	Current Condition	Resultant Change Over Time
Number of Populations	3	3	No change
Population Size	Unknown	42,000	Unknown
Habitat Area	Approximately 153 ac (62 ha)	149 ac (60 ha)	4 ac (2 ha)
Habitat Quality	High	High	No change
Population Connectivity	Spatial dispersion of historical populations	Same as historical	No change

The type of stressors affecting Ostler's peppergrass has changed over time. Precious metal mining at a commercial scale occurred in or near plant populations in the San Francisco mountain range between 1870 to 1957 (Ege 2005, pp. 29 – 30). The magnitude of this stressor is currently less today than during the commercial production period; however, lower levels of precious metal exploration activity continue today (section 4.1, Precious Metal Exploration and Mining). Stone mining began in the early 1990's and continues today. The magnitude of this stressor has increased with the two active stone mines in the species' populations (section 4.2, Stone Mining). Nonnative invasive species is a new stressor that is now present at low levels in many plant populations (section 4.3, Nonnative Invasive Species).

We do have some information regarding Ostler's peppergrass's tolerance to stressors that result in soil or habitat disturbance. In the San Francisco population, the species occurs in habitat that coincides with areas that experienced concentrated precious metal mining activity or minor quarry activity in the past, and has recolonized portions of existing dirt roads and around historic precious metal mining areas and a portion of the historic quarry area in the Copper Gulch subpopulation of the San Francisco population (section 3.2.2.3.1; Evenden 1998a, p. 4, and Appendix C, p. 24). The limited information we have suggests that Ostler's peppergrass colonizes disturbances after Frisco buckwheat has established, but this should be confirmed. The species is able to tolerate some soil and habitat disturbance in instances where disturbance is localized and where suitable soils (not bedrock) remain on the ground surface. Based on available information, we assumed Ostler's peppergrass is not tolerant of large quarry operations that result in deep excavations and more extensive impacts to population and subpopulations. We assumed the species has a similar but slower response to disturbance as Frisco buckwheat (section 5.1.1, Species Resiliency).

5.1.3 *Frisco clover*

The significant determinants of resiliency for Frisco clover are the same as those identified for Frisco buckwheat and Ostler's peppergrass: the number of healthy populations, the size of each population, the quality and quantity of the habitat factors to support the species, and the degree of connectivity between populations.

We considered the important resiliency factors for Frisco clover's historical and current condition (Table 15). The current number of Frisco clover populations is the same as the historical number of populations. Because we do not have population or species' abundance estimates prior to 1998 and have no reliable information on population trend, we cannot make comparisons between historical and current condition using abundance or trend. The current habitat area is the same as the historical habitat area, and the information we have indicates that no habitat has been lost to historical mining or stone mine operations. We also have no information that indicates a reduction in connectivity among populations has occurred.

Table 15. Summary of Resiliency factors for Frisco clover.

Resiliency Factors	Historical Condition	Current Condition	Resultant Change Over Time
Number of Populations	6	6	No change
Population Size	Unknown	15,675	Unknown
Habitat Area	Approximately 360 ac (146 ha)	360 ac (146 ha)	No change
Habitat Quality	High	High	No change
Population Connectivity	Spatial dispersion of historical populations	Same as historical	No change

The type of stressors affecting Frisco clover has changed over time. Precious metal mining at a commercial scale occurred in or near plant populations in the San Francisco mountain range between 1870 to 1957 (Ege 2005, pp. 29 – 30). The magnitude of this stressor is currently less today than during the commercial production period (section 4.1, Precious Metal Exploration and Mining). Lower levels of precious metal exploration activity continue today. Stone mining began in the early 1990's and continues today. The magnitude of this stressor has increased with the two active stone mines in the species' populations (section 4.2, Stone Mining). Nonnative invasive species is a new stressor that is now present at low levels in many plant populations (section 4.3, Nonnative Invasive Species).

Frisco clover is known to persist in locations with stressors that typically result in soil or habitat disturbance such as livestock grazing and wildfire (section 4.3, Nonnative Invasive Species; Murdoch and Welsh 1971, entire; Harrod and Halpern 2009, p. 216; Wellard *et al.* 2017, p. 3; Kitchen 2018, p. 1). However, the species' tolerance to soil and habitat disturbance from mining activity is not known because the majority of historic mining activity has occurred outside of Frisco clover habitat (other than a few areas of disturbance within the Grampian Hill population) (Evenden 1998a, p. 37 of Appendix C). Stone mine operations have also not occurred in the habitat. Therefore, we do not have evidence or information regarding the species' ability to recolonize areas following mining disturbance.

5.2 Species Redundancy: Historical and Current Condition

Frisco buckwheat, Ostler's peppergrass, and Frisco clover

Species-level redundancy reflects the ability of a species to withstand catastrophic events, and is best achieved by having multiple, widely distributed populations relative to the spatial occurrence of catastrophic events (section 1.2, Analytical Framework). Having multiple resilient populations distributed across the range of the species, will help preserve the breadth of adaptive diversity, and hence, the evolutionary flexibility of the species (representation).

The significant determinants of redundancy for the three plant species are the number of healthy populations needed to buffer against catastrophic losses, and a sufficient distribution of populations across the range to reduce the risk of a catastrophic event causing significant species level impacts. These redundancy factors for Frisco buckwheat, Ostler's peppergrass, and Frisco clover have not changed between the historical and current conditions.

We identified the following catastrophic events that have the potential to affect Frisco buckwheat, Ostler's peppergrass, and Frisco clover populations: (1) drought; (2) wildfire; (3) soil erosion from high precipitation events; and (4) landslides as a result of mining excavation activity. Three of these catastrophic events (drought, wildfire, soil erosion) would be considered naturally occurring and a landslide event that may result from mining activities would be considered an anthropogenic disturbance, and has not occurred to-date. We qualitatively evaluated and summarized each catastrophic event in terms of frequency of occurrence, species-level impact, and the spatial extent (Table 16).

Table 16. Potential catastrophic events for Frisco buckwheat, Ostler's peppergrass, and Frisco clover.

Catastrophic Event	Historic Occurrence	Current Occurrence	Species-Level Impact(s)
Drought	Periodic (decadal)	Periodic (decadal)	• Reduction in total population size. • Strength of impact dependent upon the timing, length and severity of drought conditions, as well as elevation, and aspect of plant population. Impact to species would be greater during winter/spring months. • Spatial occurrence is range-wide. Synchronous impact to all populations. Strength of impact depends on topographic features.
Wildfire	Infrequent (25 – 100 years)	Infrequent (less frequent than historic occurrence)	• Reduction in total population size. • Strength of impact dependent upon fire severity. The impact to the species would likely be low based on low plant cover. • Spatial occurrence is localized. Asynchronous impact to all populations. Unlikely to impact more than 1 - 2 populations per wildfire event.
Soil slumping from high precipitation events	Periodic (decadal)	Periodic (decadal)	• Reduction in total population size. • Possible reduction in available habitat. • Strength of impact dependent upon the length and severity of precipitation event. • Spatial occurrence is localized and dependent on topographic features. Synchrony dependent upon extent of precipitation event. Unlikely to impact more than 1 population per event.
Landslide from mining activity	None	None	• Reduction in total population size. • Possible reduction in available habitat. • Strength of impact dependent upon the extent and severity of the landslide within the population. • Spatial occurrence is localized. Asynchronous impact to all populations. Unlikely to impact more than 1 population per landslide event.

The three populations of Frisco buckwheat and Ostler's peppergrass are spread across the San Francisco mountain range and are located on different topographic features which may provide the ability to withstand more localized catastrophic events (e.g., wildfire, soil slumping), and may provide a limited ability to withstand range-wide catastrophic events (e.g., drought). Frisco clover's larger distribution and additional populations provide a greater ability to withstand localized and range-wide catastrophic events.

Under current conditions, we do not expect catastrophic weather events to result in a catastrophic loss of the species due to the intact, high quality habitat conditions and resiliency of the three species to historical and current drought conditions. As mentioned above, the habitat for all three species currently experiences high rates of soil erosion due to the naturally steep slopes. Therefore, maintaining soil surface stability and minimizing erosion rates in habitat is critical to minimize the risk and frequency of soil slumping in a population. For Frisco buckwheat and Ostler's peppergrass, we assumed Frisco buckwheat and Ostler's peppergrass will slowly recolonize occupied habitat if suitable soils remain sufficiently intact on the ground surface following a naturally occurring catastrophic event. We do not have any information about the recolonization ability of Frisco clover and we assumed the species has no recolonization ability for the purposes of this assessment. Landslides from mining activity have not occurred to date but may result from mining activity in adjacent habitat.

In summary, the redundancy of Frisco buckwheat, Ostler's peppergrass, and Frisco clover populations is and has likely always been low, like many narrow endemic species. We have no information that past catastrophic events have reduced the redundancy of the three species. Drought is the one catastrophic event that has the potential to impact all populations of the three species. The ability of the three species to retain redundancy and reduce the risk of catastrophic events is likely dependent upon maintaining high quality, intact habitat conditions that provide the necessary nutritional and reproductive resources to enable the species to persist under extreme weather events. Lastly, the very small degree of spatial and habitat heterogeneity across the population area should be maintained to reduce the chances of all populations failing concurrently due to poor environmental conditions.

5.3 Species Representation: Historical and Current Condition

Frisco buckwheat, Ostler's peppergrass, and Frisco clover

Representation is the ability of the species to adapt to physical (*e.g.*, climate conditions, habitat conditions or structure across large areas) and biological (*e.g.*, novel diseases, pathogens, predators) changes in its environment presently and into the future. Representation is essentially the evolutionary capacity or flexibility of the species (section 1.2, Analytical Framework).

The significant determinants of representation for Frisco buckwheat, Ostler's peppergrass, and Frisco clover are the genetic and phenotypic diversity of populations. Genetic diversity enables a species to adapt to changing environmental conditions (Lankau *et al.* 2011, p. 320). The genetic diversity of populations is determined by allele diversity (size of its gene pool), which is influenced by the level of gene flow among populations and the rates of genetic drift within populations. Gene flow is influenced by the degree of connectivity and landscape permeability

(Lankau *et al.* 2011, p. 320). To preserve the breadth of genetic diversity, it is important to maintain high levels of gene flow among populations.

Phenotypic diversity (physiological, morphological, ecological, and behavioral variation) is determined by the diversity of physical and biological pressures to which organisms are exposed, which vary across spatial and temporal scales. As such, species that span environmental gradients are expected to harbor the most phenotypic and genetic variation (Lankau *et al.* 2011, p. 320).

We have no information on genetic diversity for the three plant species at this time. Frisco buckwheat is a target species in a genetic study with a widespread buckwheat, *Eriogonum shockleyi*, which grows in adjacent habitat (Wolf and Lemon 2017, entire); however, results will not be available until 2018. We will incorporate the results of this study when they become available.

Regarding phenotypic diversity, we have no information that indicates there is any physiological, morphological, or behavioral variation expressed by Frisco buckwheat, Ostler's peppergrass, or Frisco clover. Populations of each species occur in similar habitat types. There may be slightly more mesic microsites based on elevation and aspect that could indicate some adaptability, or representation within each species. Unlike Frisco buckwheat and Ostler's peppergrass, Frisco clover occupies a few different soil types, including limestone, dolomite, and possibly volcanic soils, however the information we have is limited and has not been adequately assessed. For example, the soils at the Blue Mountain population may be limestone, sandstone, or siltstone. Regardless, the various soil types that Frisco clover inhabits could be used as a proxy for population representation.

5.4 Metrics for Evaluating Current Condition

Frisco buckwheat, Ostler's peppergrass, and Frisco clover

We evaluated the overall current condition and population persistence of each Frisco buckwheat, Ostler's peppergrass, and Frisco clover population based on the relevant habitat and demographic factors for the species (Table 13, Table 14, and Table 15). We selected three resiliency factors we have information on: habitat quality, habitat area, and population size. All three factors are associated with population dynamics for other rare plant species (Matthies *et al.* 2004, entire; Colling and Matthies 2006, entire).

We consider the size of the three species population abundance and the quality of occupied habitat to be the most important information we have for determining the species' resiliency. We also included habitat area because this factor is associated with plant abundance and plant biodiversity (Krauss *et al.* 2004, entire) and may change in a predictable way that can be used to estimate future population abundance. We also evaluated the percentage of habitat loss based on mining activities (precious metal and stone) within each population. We expect that plant populations with less area impacted by habitat loss will have greater resiliency. It is also important to note that population size alone may not be a good indicator of viability when impacts are occurring to populations, because of the delayed effect of size reductions after impacts have occurred (Colling and Matthies 2006, p. 970 – 971).

For our evaluation of overall population condition, we took an average of the conditions in each category. However, we weighted habitat loss more by counting it twice when “averaging” the overall condition. We did this because habitat loss can have the most impact to population resiliency. We delineated Low, Medium, and Good categories for each factor (Table 17) and assigned a value of 1, 2, or 3 for the respective categories. Each population’s overall current condition score was then calculated as the sum of all the factor scores, and was translated into an overall current condition category of low, moderate, or good. We divided the possible overall average condition scores into three non-equal intervals representing the breadth of possible scores. Average scores of 1 – 1.66 (0.66 spread) means the population is in overall Low condition; 1.67 – 2.33 (0.67 spread) is an overall Moderate condition; and 2.34 – 3 (0.66 spread) is an overall Good condition. This ranking slightly favors a Moderate condition category over a Good or Low condition category, and the ranking categories should be updated when new information becomes available. The condition score summary is detailed in Appendix A.

We considered the following in our delineation of condition categories:

- Nonnative plant cover thresholds correspond to Daubenmire cover classes (Elzinga *et al.* 2009, p. 179).

- Population size categories were delineated based on consideration of Schonewald-Cox *et al.* (1983) and Pavlik (1996, pp. 135 – 137), and uncertainty due to lack of species-specific data.

- Habitat loss categories based on consideration of threshold values for habitat loss for endemic plant species (Yin *et al.* 2016, pp. 10-11 EV).

Table 17. Metrics for evaluating current condition for Frisco buckwheat, Ostler’s peppergrass, and Frisco clover.

Current Condition				
Condition	Habitat Quality	Habitat Area (Acres)	Population Size (Individuals)	Habitat Loss Category
Good	(1) Nonnative plant cover 0 - 5%, or (2) Recent disturbance within <5% of habitat area	51 or greater	> 5,000	0 - 5% (Low Loss)
Moderate	(1) Nonnative plant cover 0 - 5%, or (2) Recent disturbance within 5 - 10% of habitat area	26 - 50	500 – 5,000	5.1 – 10% (Moderate Loss)
Low	(1) Nonnative plant cover 6 - 25%, or (2) Recent disturbance within >10% of habitat area	25 or less	< 500	>10% (High Loss)

5.5 Current Condition Results

5.5.1 *Frisco buckwheat*

The available information indicates that the current range of Frisco buckwheat occurs within three populations in the San Francisco mountain range (Figure 14; Table 18). A substantial portion of the species' habitat is intact. Portions of the habitat were historically used for precious metal mining operations; however the species persisted and is slowly recolonizing disturbed portions of the occupied habitat (section 3.2.1, Population Status). Frisco buckwheat's current condition is not a direct result of any ongoing conservation measures. Rather, the current condition is a direct result of the low level of habitat loss to-date in the populations. The species maintains a similar resiliency, redundancy, and representation as it did historically in the Grampian Hill population. We estimate the Cupric Mine and San Francisco populations have lost ten percent and six percent, respectively, of occupied habitat to-date.

Resiliency –The Grampian Hill and San Francisco populations are the most resilient based on all of the habitat and demographic factors contributing to resiliency. These factors likely provide those two Frisco buckwheat populations the ability to withstand stochastic events such as drought or wildfire. The Cupric Mine population is in Moderate condition based on the habitat and demographic factors contributing to resiliency. The Moderate condition of this population may result in a lower ability of this population to withstand stochastic events. The moderate amount of habitat loss to-date does not change the overall current condition of the Cupric Mine and San Francisco populations.

Redundancy – Like many narrow endemic species, the redundancy of Frisco buckwheat is, and has likely always been, inherently low as a result of its limited geographical area, and the fact that it comprises only three populations. However, these populations are spread across the San Francisco mountain range and on different topographic features which may provide the ability to withstand more localized catastrophic events (e.g., wildfire, soil slumping), and may provide a limited ability to withstand range-wide catastrophic events (e.g., drought).

Representation – We do not have information on the genetic diversity of Frisco buckwheat. Therefore, we considered whether there are other types of representative diversity that could indicate some ability to adapt to change, such as morphological or phenological differences, or different habitat types within the species' range. We are not aware of any significant morphological or phenological differences for the species. Preserving the species' representation requires maintaining the current number of populations within the range and the very small degree of spatial and habitat heterogeneity within populations. The current distribution is the same as the historical distribution, and we have no information that indicates a reduction in genetic diversity or connectivity among populations has occurred.

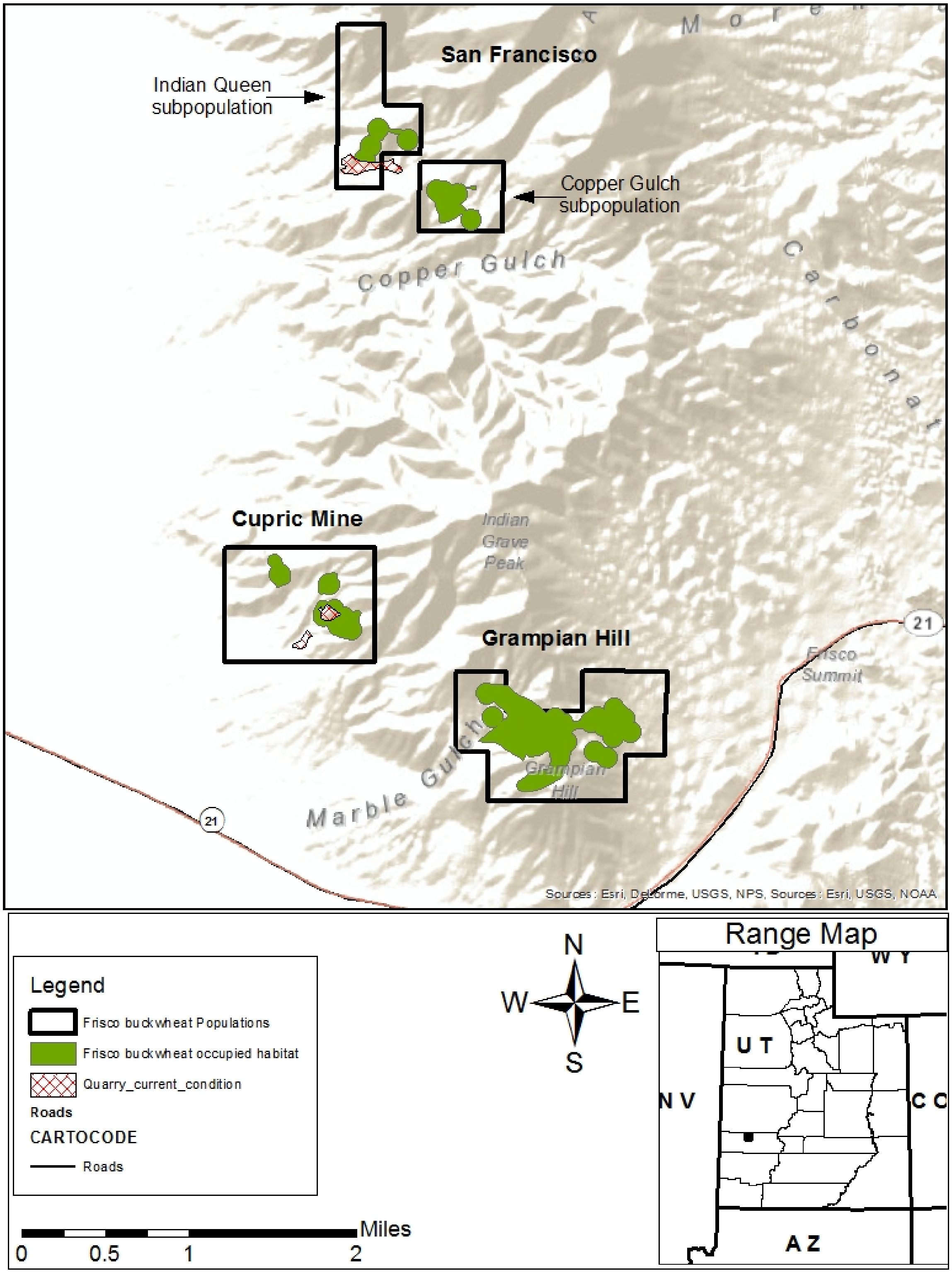

Figure 14. Frisco buckwheat current habitat and stone mine (quarry) locations.

Table 18. Current Condition for Frisco buckwheat populations.

Population	Habitat Factors		Demographic Factors	Habitat Loss Category	Overall Current Condition (Resiliency)
	Habitat Quality	Habitat Area	Population Size		
Grampian Hill	Good	Good	Good	Good	Good
Cupric Mine	Good	Moderate	Moderate	Moderate	Moderate
San Francisco	Good	Good	Good	Moderate	Good

5.5.2 *Ostler's peppergrass*

The available information indicates that the current range of Ostler's peppergrass occurs within three populations in the San Francisco mountain range (Figure 15; Table 19). A substantial portion of the species' habitat is intact. Portions of the habitat were historically used for precious metal mining operations. Despite human use in the habitat and surrounding lands since the 1850's, Ostler's peppergrass has persisted and is slowly recolonizing disturbed portions of the occupied habitat (section 3.2.2, Population Status). It is important to note that Ostler's peppergrass' current condition is not a direct result of any ongoing conservation measures. Rather, the current condition is a direct result of the level of habitat loss to-date in the populations. The species maintains a similar resiliency, redundancy, and representation as it did historically in two (Grampian Hill and San Francisco) of the three populations. We estimate the Cupric Mine population has lost 15 percent of occupied habitat to-date.

Resiliency –The Grampian Hill and San Francisco populations are the most resilient based on their Good population size, habitat area, and habitat quality rankings. These factors likely provide these two Ostler's peppergrass populations the ability to withstand stochastic events such as drought or wildfire. The Cupric Mine population ranked as Moderate resiliency due to its Moderate size and habitat area. The large amount of habitat loss to-date does not change the overall current condition of the Cupric Mine population. The Moderate condition of this population may result in a lower ability of the species to withstand stochastic events.

Redundancy – Like many narrow endemic species, the redundancy of Ostler's peppergrass is and has likely always been, inherently low as a result of its limited geographical area, and the fact that it comprises only three populations. However, these populations are spread across the San Francisco mountain range and on different topographic features that may provide the ability to withstand more localized catastrophic events (e.g., wildfire, soil slumping), and may provide a limited ability to withstand range-wide catastrophic events (e.g., drought).

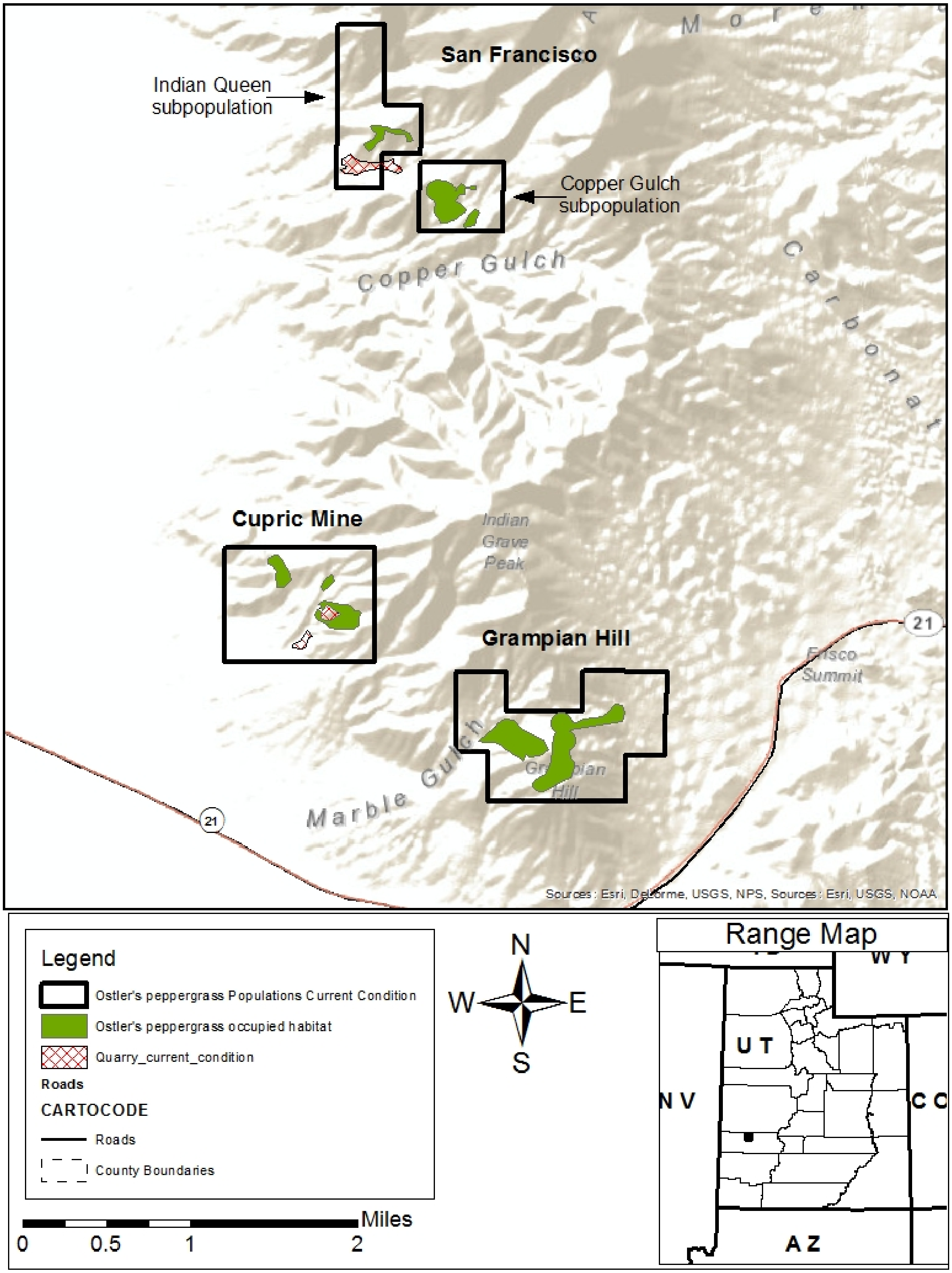

Figure 15. Ostler's peppergrass current habitat and stone mine (quarry) locations.

Table 19. Current Condition for Ostler's peppergrass populations.

Population	Habitat Factors		Demographic Factors	Habitat Loss Category	Overall Current Condition (Resiliency)
	Habitat Quality	Habitat Area	Population Size		
Grampian Hill	Good	Good	Moderate	Good	Good
Cupric Mine	Good	Moderate	Moderate	Low	Moderate
San Francisco	Good	Moderate	Good	Good	Good

Representation – We do not have information on the genetic diversity of Ostler's peppergrass. Therefore, we considered whether there are other types of representative diversity that could potentially indicate some ability to adapt to change, such as morphological or phenological differences, or different habitat types within the species' range. We are not aware of any significant morphological or phenological differences for the species. Preserving the species' representation requires maintaining the current number of populations within the range and the very small degree of spatial and habitat heterogeneity within populations. The current distribution is the same as the historical distribution, and we have no information that indicates a reduction in genetic diversity or connectivity among populations has occurred.

5.5.3 *Frisco clover*

The available information indicates that the current range of Frisco clover occurs within six populations across four mountain ranges (Figure 16; Table 20). A substantial portion of the species' habitat is currently relatively intact. The habitat was largely adjacent to historical precious metal exploration and mining areas and more recent stone mine areas. Since there is minimal disturbance in the habitat, we do not have information on its ability to recolonize following disturbance. It is important to note that Frisco clover's current condition is not a direct result of any ongoing conservation measures. Rather, the current condition is a direct result of minimal disturbance in the species' habitat to-date. The species currently maintains a similar resiliency, redundancy, and representation as it did historically in all populations.

Resiliency – Five of the six Frisco clover populations have good resiliency. Of those five populations, the Grampian Hill, Tunnel Springs and Wah Wah Mountain populations are the most resilient based on a their combination of population size, habitat area, and habitat quality. The lack of habitat loss for all populations is a big factor contributing to the current condition of all populations to withstand stochastic events such as drought or wildfire. The Blue Mountain population is in Moderate condition due to its small size and habitat area which may result in a lower ability to withstand stochastic events. However, it is important to note that the current condition of the Blue Mountain populations is the same as its historical condition.

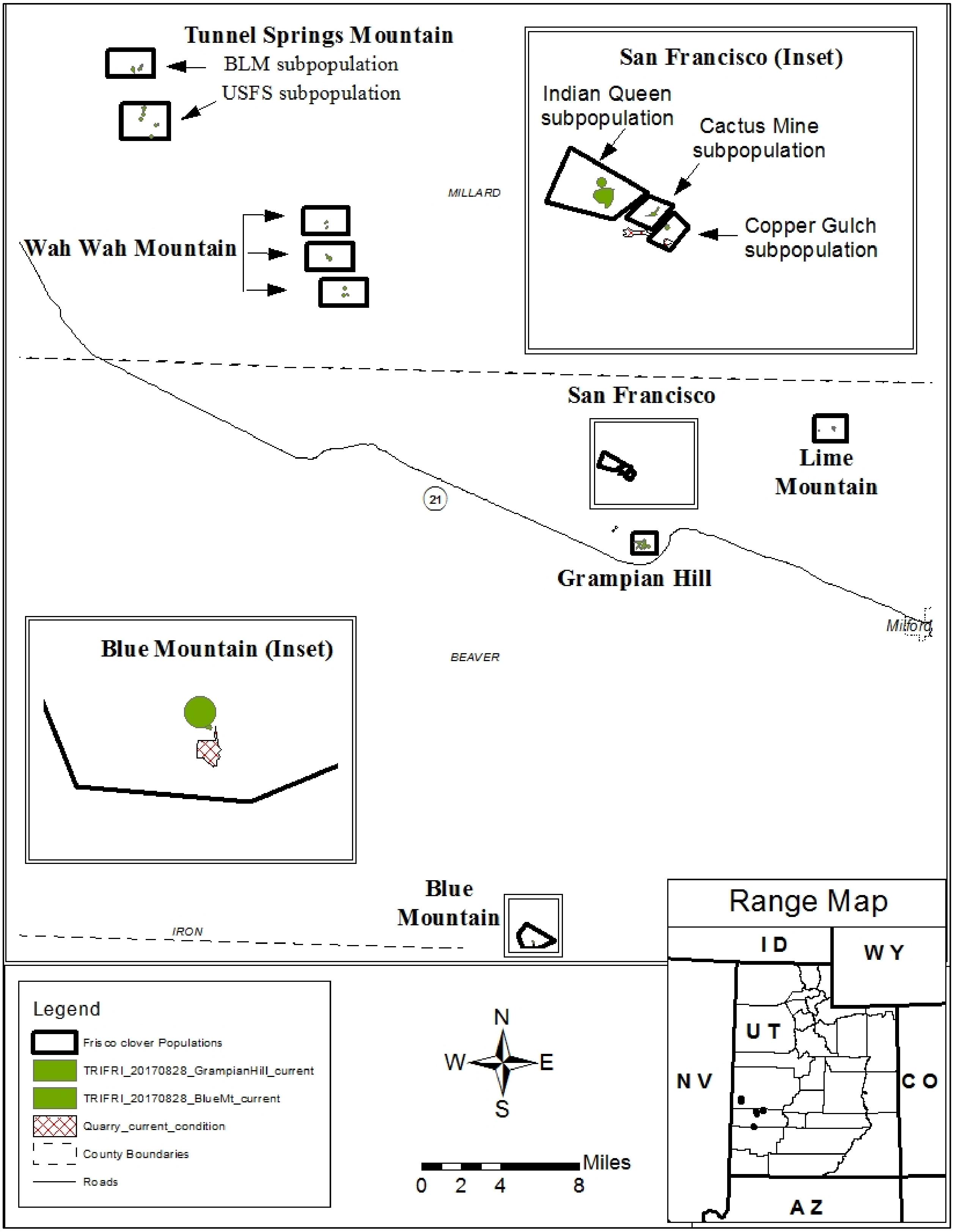

Figure 16. Frisco clover current habitat and stone mine (quarry) locations.

Table 20. Current Condition for Frisco clover populations.

Population	Habitat Factors		Demographic Factors	Habitat Loss Category	Overall Current Condition (Resiliency)
	Habitat Quality	Habitat Area	Population Size		
Blue Mountain	Good	Low	Low	Good	Moderate
Grampian Hill	Good	Moderate	Good	Good	Good
San Francisco	Good	Moderate	Moderate	Good	Good
Lime Mountain	Good	Low	Moderate	Good	Good
Tunnel Springs Mountains	Good	Good	Moderate	Good	Good
Wah Wah Mountains	Good	Good	Moderate	Good	Good

Redundancy – Like many narrow endemic species, the redundancy of Frisco clover is and has likely always been, inherently low to moderate as a result of its small geographical range. Frisco clover has more redundancy than Frisco buckwheat and Ostler's peppergrass with six populations compared to three populations for the other two species. Frisco clover has resilient populations spread across four mountain ranges and on different topographic features that should provide the ability to withstand localized catastrophic events (wildfire, soil slumping), and may provide some ability to withstand range-wide catastrophic events (drought).

Representation – We do not have information on the genetic diversity of Frisco clover. Therefore, we considered whether there are other types of representative diversity that could potentially indicate some ability to adapt to change, such as morphological or phenological differences, or different habitat types within the species' range. We are not aware of any significant morphological differences for the species. Phenological differences include a tolerance to a variety of soils, including limestone and dolomite, although we need additional information regarding the range of soils the species occupies. Preserving the species' representation requires maintaining the current number of populations within the range and the very small degree of spatial and habitat (soil) heterogeneity within populations. The current distribution is the same as the historical distribution, and we have no information that indicates a reduction in genetic diversity or connectivity among populations has occurred.

5.5.4 Uncertainties Relating to Current Condition

We do not have demographic or trend monitoring for Frisco buckwheat, Ostler's peppergrass, and Frisco clover populations and therefore we used the best available population estimate and habitat conditions to inform our population health and resilience assessment. For many habitat conditions, we do not have information to quantify the conditions needed by the species, therefore we made assumptions about what represents "good", "moderate", and "low" conditions for the species, and in some cases used qualitative assessments where quantitative data or habitat conditions were lacking. We acknowledge that for these apparently moderate to long-lived plant species, we do not know what constitutes a minimum viable population size. Where impacts occur it will likely be necessary to evaluate viability through detailed demographic studies. We also made assumptions of the level of disturbance and habitat loss based on the best available information in our records because we do not have an evaluation or delineation of actual levels. Actual levels of disturbance may be larger than what we assumed.

Chapter 6. Species Future Condition and Status

We described the natural history and distribution of Frisco buckwheat, Ostler's peppergrass, and Frisco clover in Chapter 2. We considered the ecological needs for each species in Chapter 3, and the current condition for each species in Chapters 4 and 5. In this Chapter, we evaluate each species expected future condition using projections and plausible scenarios. We utilized the current condition as the baseline from which to evaluate changes to those factors considered important to Frisco buckwheat, Ostler's peppergrass, and Frisco clover.

The viability of Frisco buckwheat, Ostler's peppergrass, and Frisco clover depends on maintaining multiple self-sustaining populations throughout their range into the future. Given their dependence on occupied habitat for all stages of their life cycle, we consider the presence of relatively stable, undisturbed habitat that allows for population stability and growth under various climate conditions, and connectivity between populations to be necessary to support viability.

Future changes in precious metal exploration and mining, stone mining, and the potential for cumulative effects of these two mining operations with nonnative invasive species and climate change are the primary stressors expected to influence the future condition of Frisco buckwheat, Ostler's peppergrass, and Frisco clover. We developed our future scenarios based on these primary stressors while acknowledging there is uncertainty on how these stressors may change singly and cumulatively, and their effects on each plant species. We incorporated future climate conditions into the future scenarios using moderate climate conditions that extend to 2049 and 2050. We did not consider a longer time-frame or evaluate multiple climate scenarios since climate change is not identified as a primary stressor for the three plant species.

6.1 Climate Change

As defined by the Intergovernmental Panel on Climate Change (IPCC), the term ''climate'' refers to the mean and variability of different types of weather conditions over time, with 30 years being a typical period for such measurements, although shorter or longer periods also may be used (IPCC 2013a, p. 1450). The term ''climate change'' thus refers to a change in the mean or the variability of relevant properties, which persists for an extended period, typically decades or longer, due to natural conditions (e.g., solar cycles) or human-caused changes in the composition of atmosphere or in land use (IPCC 2013a, p. 1450). Scientific measurements spanning several decades demonstrate that changes in climate are occurring. In particular, warming of the climate system is unequivocal, and many of the observed changes in the last 60 years are unprecedented over decades to millennia (IPCC 2013b, p. 4). The current rate of climate change may be as fast as any extended warming period over the past 65 million years and is projected to accelerate in the next 30 to 80 years (National Research Council 2013, p. 5).

Scientists use a variety of climate models, which include consideration of natural processes and variability, as well as various scenarios of potential levels and timing of greenhouse gas emissions, to evaluate the causes of changes already observed and to project future changes in temperature and other climate conditions. Model results yield very similar projections of average global warming until about 2030, and thereafter the magnitude and rate of warming vary through the end of the century depending on the assumptions about population levels, emissions of greenhouse gases, and other factors that influence climate change. Thus, absent extremely rapid stabilization of GHGs at a global level, there is strong scientific support for projections that warming will continue through the 21st century, and that the magnitude and rate of change will be influenced substantially by human actions regarding greenhouse gas emissions (IPCC 2013b, 2014; entire). Global climate projections are informative, and, in some cases, the only or the best scientific information available for us to use. However, projected changes in climate and related impacts can vary substantially across and within different regions of the world (e.g., IPCC 2013c, 2014; entire) and within the United States (Melillo *et al.* 2014, entire). Therefore, we use ‘‘downscaled’’ projections when they are available and have been developed through appropriate scientific procedures, because such projections provide higher resolution information that is more relevant to spatial scales used for analyses of a given species (Glick *et al.* 2011, pp. 58–61, for a discussion of downscaling).

Since we are not aware of a downscaled climate model for the range of Frisco buckwheat, Ostler’s peppergrass, and Frisco clover, we used climate change data from the Multivariate Adaptive Constructed Analogs (MACA) website that uses a downscaling method for model output from 20 global climate models to a 2.5 to 4 mi (4 to 6 km) resolution (https://climate.northwestknowledge.net/MACA/index.php). We used two different emission scenarios, a low emission scenario and a high emissions scenario. The low emissions scenario is the Representative Concentration Pathways (RCP) 4.5 emission scenario and the high emission scenario is the RPC 8.5 emission scenario used by the latest IPCC report. RCP 4.5 is an intermediate emissions scenario where atmospheric carbon dioxide (CO2) concentrations are expected to equal approximately 650 ppm after the year 2100. In RCP 8.5, emissions aggressively increase to approximately 1370 ppm CO2 after the year 2100 (IPCC 2014, p. 57; USGS 2017, p. 3). For comparison, current atmospheric CO2 concentrations are around 400 ppm (USGS 2017, p. 3).

The results of our “downscaled” climate evaluation indicate future climate conditions will be warmer in all seasons under both emission scenarios (Lewinsohn 2017b, entire). The difference in temperature increase between the two scenarios is within 1.3^{O}F through 2050. Summer temperatures are predicted to increase the most relative to the other seasons under both scenarios. In general, temperatures are predicted to increase by approximately 4.4^{O}F under the intermediate emissions scenario (RCP 4.5) and approximately 5.5^{O}F under the high emissions scenario (RCP 8.5). For precipitation, future spring precipitation is expected to be similar to the historical spring precipitation average through 2050 under both scenarios. Precipitation during the other seasons is expected to increase under both scenarios. In general, summer, fall and winter precipitation is predicted to increase between 6.5 – 13.8 percent under the low emission scenario and between 7.9 – 18 percent under the high emission scenario.

We recognize the effects of increased temperature and precipitation can confound each other, and the effects of increased temperature dominate increased precipitation in some climate models (Stewart *et al.* 2004, p. 224). As temperatures warm, so does evaporation, sometimes negating the effects of increased precipitation because soil water storage may decrease. Evaporative deficit is the difference between water available in the soil and water lost to evapotranspiration. As evaporative deficit increases, the landscape becomes drier, and drought conditions increase.

In order to consider a more integrated measure of the combined effect of increased temperature and precipitation levels, we considered a measure of evaporative deficit instead of precipitation alone for our predictions of drought conditions. The evaporative deficit measure is not available on the MACA website, so we utilized the USGS National Climate Change Viewer (NCVV) at the following website: https://www2.usgs.gov/climate_landuse/clu_rd/nccv/viewer.asp. The NCVV averages the results of 33 global climate models and provides predictions for the same two emissions scenarios. We evaluated the same two emissions scenarios for Millard County, Utah during the future time period, 2025 to 2049. Under both scenarios, the evaporative deficit is predicted to be significantly different than the historical period during the growing season (March – October). The pattern of the evaporative deficit over the year is the same under both scenarios. The evaporative deficit steadily increases during the spring, peaks in July, and steadily decreases during the fall. The difference between the predicted and historical peak July evaporate deficits is similar for both emission scenarios; 10.2 mm (0.40 in) under the intermediate emissions scenario and 11 mm (0.43 in) under the high emissions scenario. Interestingly, the annual evaporative deficit is lower under the high emissions scenario (6.7 mm/month (0.26 in/month)) compared to the intermediate emissions scenario (8.7 mm/month (0.34 in/month)). This indicates the additional precipitation under the high emissions scenario will not be offset by the slightly higher temperatures resulting in a less dry landscape compared to the intermediate emissions scenario. Nevertheless, both scenarios indicate the range of Frisco buckwheat, Ostler's peppergrass, and Frisco clover may be drier in the future compared to historical conditions.

Future climate conditions have the potential to impact the future condition of Frisco buckwheat, Ostler's peppergrass, and Frisco clover. Here, we discuss what could happen in general to the species' range and abundance under warmer and drier conditions based upon what we know about the biology of the species.

<u>Range Effects:</u> Accelerating rates of climate change of the past two or three decades indicate that the extension of species' geographic range boundaries toward the poles or to higher elevations by progressive establishment of new local populations will become increasingly apparent in the relatively short term (Hughes 2005, p. 60). We do not have evidence of a range contraction or shift for the Frisco buckwheat, Ostler's peppergrass, and Frisco clover. All three species have the ability to occupy different slope aspects based on their current distribution. We anticipate that all three species should have the ability to migrate to favorable microsites within population areas that are cooler and wetter, but only Frisco clover has the ability to migrate

beyond existing population areas to other areas of suitable habitat based on its larger range and wider soil tolerance.

Future climate conditions have the potential to reduce the number of suitable microsites available within population areas. There is also the potential for a range reduction for all three species, particularly in combination with other stressors. When we consider characteristics that contribute to vulnerability to climate change such as poor dispersal ability, highly specific habitat requirements, and a limited ability to shift distribution in response to environmental conditions, Frisco buckwheat and Ostler's peppergrass would likely rank high on the vulnerability index at the species-level, while Frisco clover would likely receive a lower rank (Young *et al* 2012, 133 - 139).

Plant Effects: Frisco buckwheat, Ostler's peppergrass, and Frisco clover and other long-lived plants in semi-arid environments may be less vulnerable to the effects of climate change if future climate conditions are within the historic natural climatic variation experienced by each species (Tielbörger *et al.* 2014, p. 7). As long-lived species, they have the potential to exhibit a small or delayed response to climate conditions compared to shorter-lived species (Tielbörger *et al.* 2014, p. 2). They can employ adaptations in order to survive periods of resource limitation (i.e., drought), and can respond more slowly with respect to changes in abundance compared to changes in biomass and reproduction (Tielbörger *et al.* 2014, p. 5; Schwinning and Sala 2004, entire). We expect plant abundance to be less sensitive to drought conditions compared to growth, reproduction, and seedling recruitment.

We also expect plant abundance to be more sensitive to the duration of drought conditions rather than the severity of drought in a given year based on the legacy effect of past precipitation events (Evans *et al.* 2011, entire). Increased temperatures have the potential to result in increased growth and reproduction if water is not limiting or reduced growth and reproduction if water is limiting (Bita and Gerats 2008, p. 1; Warwell and Shaw 2017, p. 1213). We expect that plants will exhibit a complex response to increased temperatures based on the availability of moisture during the growing season, and the species' temperature tolerance and threshold. Importantly, a species' ability to adapt to changing climate conditions is dependent on its adaptive capacity (existing genetic variation or representation) (Warwell and Shaw 2017, p. 1213).

Climate change effects present substantial uncertainty regarding the future environmental conditions in the range of Frisco buckwheat, Ostler's peppergrass, and Frisco clover, but may place an added stress on the species and its habitat, particularly where other stressors are present. Despite characteristics that make the three species vulnerable to climate change, our climate evaluation is too speculative to determine the severity of this stressor to Frisco buckwheat, Ostler's peppergrass, and Frisco clover at the population level. Long-lived perennial plants exhibit a range of drought and temperature sensitivity based on physiological (photosynthetic pathway), morphological (rooting depth), and inherent genetic variability (Warwell and Shaw 2017, p. 1205), which all contribute to a species' tolerance (Hoover *et al.* 2015, p. 7 – 11). Additional information regarding each species drought and temperature tolerance is needed for a better assessment of future climate effects.

Nevertheless, for the purpose of our future condition evaluation, we consider resilience of plant populations to future climate conditions. Our evaluation is based on consideration of two factors: (1) a downscaled evaluation of the current solar radiation load for occupied habitat; and (2) the presence of plants on multiple aspects. We used the solar radiation load (insolation) as a proxy for estimating the evaporative demand within the habitat by population because radiation affects the temperature and water balance of soils and can influence the landscape-scale distribution of plants (Pierce Jr. *et al.* 2005, entire). We calculated the solar radiation load of occupied habitat for each plant population based on fine-scaled topographic features that include elevation, slope, aspect, and hillshade (nearby topography that influences shading) using methods identified in Fu and Rich (2002). We used a digital elevation model with a 323 ft^2 (30 m^2) scale. Methods are discussed in Appendix B.

We incorporated aspect as a separate category to give it more weight in our analyses. The complex topography within populations and the presence of multiple aspects can strongly influence temperature and moisture levels at a smaller scale than our radiation load analysis was able to provide. The presence of multiple aspects is likely an important consideration due to the high topographic relief and variability within the populations which likely provide cooler and moister habitat conditions (Fu and Rich 2002, p. 26 – 27; Fekedulegn *et al.* 2003, p. 409 – 410; Opedal *et al.* 2015, entire; Graae *et al.* 2017, entire). We assumed that populations with lower current relative radiation loads and multiple aspects will be more resilient to future climate conditions because we expect a lower departure from historic soil moisture and temperature levels. We do not compare emissions scenarios rather we consider the composite prediction of warmer temperatures, and slight increases in seasonal precipitation in the future (Lewinsohn 2017b, entire).

6.1.1 Calculating Climate Resilience Scores

We delineated low, moderate, and good categories for population-level climate resilience based on the consideration of relative radiation load and the presence of multiple aspects (Table 21). For relative radiation load, we took the spread of scores for all three plant species and divided them into three equal intervals for our low, moderate, and high ranking. For the aspect factor, there had to be more than one aspect in order to have multiple aspects. The aspect evaluation can be refined with a more detailed analysis in the future. The combinations of both factors favor the moderate climate resiliency category over the good and low categories.

Table 21. Metrics for evaluating climate resilience.

Future Climate Resilience Categories		
Resilience	**Relative Radiation Load**	**Multiple Aspects (Y/N)**
Good	Low	Yes
Moderate	Low	No
	Moderate	Yes
	High	Yes
Low	Moderate	No
	High	No

In summary, our evaluation indicates that the Grampian Hill population for Ostler's peppergrass and Frisco clover (Table 23, Table 24) will be the most resilient to future climate conditions because of the combination of low relative radiation loads and multiple aspects. All but one (Blue Mountain) of the remaining populations are in the moderately resilient category. These populations have higher relative radiation loads and contain multiple aspects. Only the Blue Mountain population of Frisco clover (Table 24) has a low climate change resilience because it does not contain multiple aspects.

Table 22. Climate change resilience for Frisco buckwheat populations.

Population	Relative Radiation Load	Multiple Aspects (Y/N)	Climate Change Resilience
Grampian Hill	Moderate	Yes	Moderate
Cupric Mine	Moderate	Yes	Moderate
San Francisco	High	Yes	Moderate

Table 23. Climate change resilience for Ostler's peppergrass populations.

Population	Relative Radiation Load	Multiple Aspects (Y/N)	Climate Change Resilience
Grampian Hill	Low	Yes	Good
Cupric Mine	Moderate	Yes	Moderate
San Francisco	High	Yes	Moderate

Table 24. Climate change resilience for Frisco clover populations.

Population	Relative Radiation Load	Multiple Aspects (Y/N)	Climate Change Resilience
Blue Mountain	Moderate	No	Low
Grampian Hill	Low	Yes	Good
San Francisco	Moderate	Yes	Moderate
Lime Mountain	Moderate	Yes	Moderate
Tunnel Springs Mountains	Moderate	Yes	Moderate
Wah Wah Mountains	Moderate	Yes	Moderate

6.1.2 Conservation Measures

We are not aware of any ongoing conservation measures involving Frisco buckwheat, Ostler's peppergrass, and Frisco clover and climate change. Given the three species' limited ability to migrate and establish outside of their existing ranges, the primary conservation measures should be to protect the majority of individuals within plant populations in order to preserve the breadth of genetic diversity, and to support the adaptive capacity (representation) of the three species to develop a tolerance of future climate conditions. Ensuring that plant population areas are in high condition may also help buffer the loss of individuals and minimize an exacerbated effect from vegetative competition for moisture by nonnative invasive species.

6.1.3 Uncertainty

Climate models have great utility because they allow us to make predictions of how climate may change in the future, but their results should be interpreted cautiously. Models are mathematical representations of what can happen, but they do not always accurately predict future events. Climate models have greatly improved in recent years, but projections for precipitation remain less reliable than those for surface temperature (O'Gorman and Schneider 2009, p. 14744;

Trenberth 2011, p. 133; IPCC 2014, p. 56). For our analysis of Frisco buckwheat, Ostler's peppergrass, and Frisco clovers' future condition, we acknowledge the innate uncertainty associated with climate modeling. We also recognize these models represent some of the best available scientific data we can utilize for predicting the species' resilience to future climate conditions. Our climate change resilience evaluation is uncertain because we do not have species-specific information. We limited our evaluation to relative radiation loads and did not use this information to develop predictions of temperature or soil moisture conditions. We also performed a simple assessment of aspect that can be improved in future analyses and with species-specific information.

6.2 Development of Future Scenarios

Given our uncertainties regarding the future exposure of precious metal exploration and mining and stone mining, we evaluated Frisco buckwheat, Ostler's peppergrass, and Frisco clover under four plausible future scenarios, and these scenarios were designed to encompass the full range of plausible future conditions.

These scenarios include:

1. Scenario 1 – Conservation

    - Precious metal exploration and mining activities are limited to exploration that occurs outside of plant population areas. Exploration activities do not result in the development of commercial operations in or near plant populations in the San Francisco mountain range as well as in or near plant populations located in other mountain ranges because of voluntary protections.

    - Stone mining activities cease because of voluntary measures and are reclaimed where they are directly impacting plant populations (Cupric Mine and San Francisco populations).

    - Stone mining activities are relocated to avoid direct impacts to plant populations and indirect impacts to plant population areas in order to meet the avoidance buffers and surface disturbance caps we identified for precious metal exploration and mining (section 4.1.2.2, Precious Metal Exploration and Mining).

    - Nonnative invasive species' levels do not increase outside of existing stone mine perimeters into intact habitat.

    - Climate resilience of populations is incorporated into the population condition evaluation.

2. Scenario 2 – Low to Moderate Level Precious Metal Exploration and Mining

- We did not consider the stone mining stressor in this scenario so that we could evaluate the relative contribution of the precious metal and mining stressor to each species resiliency, redundancy, and representation.

- For the purposes of this scenario, our precious metal evaluation area includes the deposits and targets identified in the Frisco mineral system (Figure 9; Figure 20; Figure 21).

- Precious metal exploration will occur within the three species' Grampian Hill populations and the San Francisco Copper Gulch subpopulations of Frisco buckwheat and Ostler's peppergrass (rated as High Potential in Table 10). We assumed future mineral exploration activities will occur within the evaluation area at a low level based on the low extent and frequency of past exploration activity. We assumed precious metal exploration would not change the population size condition category of plant populations. We assumed future exploration would not result in greater than 5 percent habitat loss (Good condition category) based on negligible past impacts to plant populations. This scenario is consistent with the frequency and extent of historical precious metal exploration.

- We assumed future precious metal mining activities would occur at moderate levels at two high likelihood locations, the Imperial Mine and the Cactus Mine, within the Grampian Hill and Cactus Mine deposits. The two future mining locations, access roads, and nearby processing areas are depicted in Figure 20 and Figure 21, and do not overlap with plant populations. This scenario takes into account the low likelihood that precious metal exploration would result in future mining but also identifies two likely locations for future mining based on best available scientific and commercial information (section 4.1, Precious Metal Exploration and Mining).

- Nonnative invasive species' levels do not increase outside of disturbance areas into intact habitat. We assumed the combination of future exploration and mining would result in a Moderate condition category for habitat quality within the evaluation area. This assumption only affects habitat quality of the Grampian Hill population for the three species.

- Climate resilience of populations is incorporated into the population condition evaluation.

3. Scenario 3 – Moderate Level Stone Mining

    - We did not consider the precious metal exploration and mining stressor in this scenario so that we could evaluate the relative contribution of the stone mining stressor to each species' resiliency, redundancy, and representation.

    - Stone mining activities continue and expand at active mines (Courgraph, Southern White/Mountain Rose, and Indian Queen) in and near plant populations (Table 11; Figure 17; Figure 18; Figure 19). We did not anticipate stone mining activities to continue at the Old Quarry. We assumed that stone mining impacts would result in Low condition categories for locations with habitat areas 25 ac or less in size, where habitat loss that is greater than 10 percent, and where population size that is less than 500 plants. Stone mining results in the loss of all plants within the stone mine footprint.

    - Nonnative invasive species levels do not exceed trace amounts. We assumed nonnative invasive species would be controlled and moderate habitat quality would result for populations or subpopulations impacted by stone mining based on the use of best reclamation practices which allow for future colonization by Frisco buckwheat, Ostler's peppergrass, and Frisco clover. We assumed high habitat quality would remain for subpopulations not impacted by stone mining.

    - Climate resilience of populations is incorporated into the population condition evaluation.

4. Scenario 4 – High Level Stone and Precious Metal Mining

    - Our High Level Stone and Precious Metal Mining Scenario is consistent with, but slightly larger than, the upper estimated predictions of the development potential for copper, lead, and zinc, and estimated disturbance levels identified in the BLM Mineral Potential Report (section 4.1, Precious Metal Exploration and Mining; BLM 2012, pp. 14, 129, 143, 145). For the purposes of this scenario, our evaluation area includes the Cactus Mine and Grampian Hill deposits and a 1,640 ft (500m) buffer around these two deposits where we predict higher intensity mineral exploration activities, future mining, and associated infrastructure could occur (Figure 22; Figure 23; Figure 24; Alderan 2017, p. 5). The total acreage for the evaluation area and buffer is 2,622 ac (1,061 ha). The BLM Mineral Potential Report did not identify areas within the San Francisco Mineral District where disturbance was likely to occur, thus our analysis relies on location information from mining development companies and the Utah Geological Survey.

    - Precious metal exploration and mining would occur within the three species' Grampian Hill populations and the San Francisco Copper Gulch subpopulations of Frisco buckwheat and Ostler's peppergrass (rated as High Potential in Table 10). We assumed that exploration and mining impacts would result in a Low condition category where populations overlap with the evaluation area, where habitat areas are 25 ac or less in size, and where habitat loss is greater than 10 percent. We did not assign a condition category for population size where the evaluation area overlaps with plant populations because we did not have sufficient data on the number of plants that occur within the evaluation area. Thus, we removed the population size category from our condition calculation.

- Stone mining activities continue and expand at active mines (Courgraph, Southern White/Mountain Rose, and Indian Queen) in and near plant populations (Table 11). We did not anticipate stone mining activities to continue at the Old Quarry. Stone mining is predicted to result in the loss of the Frisco buckwheat and Ostler's peppergrass Cupric Mine populations and San Francisco Indian Queen subpopulations; and the Frisco clover Blue Mountain population through a combination of habitat loss and slope subsidence.

- Nonnative invasive species' levels increase at locations of precious metal exploration and mining and stone mining operations.

- Climate resilience of populations is incorporated into the population condition evaluation.

Scenarios 2, 3, and 4, were characterized with a low, moderate, or high level for each mining stressor based on the extent of the stressor on the landscape. We then used criteria identified in Table 25 to determine the extent of each scenarios effects within plant populations. We did not identify an extent level for mining stressors in the Conservation Scenario. For each scenario, we evaluated the likely condition of each plant population with respect to the same metrics used in our evaluation of current condition including habitat quality, habitat area, population size, and habitat loss (Table 25). Our assessment of climate change resilience was incorporated into the future condition ranking as a metric equal in value to the habitat quality, habitat area, and population size metrics. We then categorized each factor as "Good," "Moderate," or "Low" condition based on the scoring result of each population. These scenarios consider how conditions are likely to change for the species within a 20-year timeframe based on a general BLM Resource Management Plan (RMP) planning timeframe. This timeframe is longer than the 10-year timeframe economists generally use to predict market-driven industrial development (Industrial Economics, Inc. 2014, p. 20). The results of our analysis are described below.

Table 25. Metrics for evaluating future condition for Frisco buckwheat, Ostler's peppergrass, and Frisco clover.

Future Condition					
Condition	**Habitat Quality**	**Habitat Area (Acres)**	**Population Size (Individuals)**	**Habitat Loss Category**	**Climate Change Resilience**
Good	(1) Nonnative plant cover 0 - 5%, or (2) Recent disturbance within <5% of habitat area	51 or greater	> 5,000	0 - 5% (Low Loss)	(1) Low radiation load, and (2) Multiple aspects
Moderate	(1) Nonnative plant cover 0 - 5%, or (2) Recent disturbance within 5 - 10% of habitat area	26 - 50	500 – 5,000	5.1 – 10% (Moderate Loss)	(1) Low radiation load, and one aspect; or (2) Moderate or high radiation load, and multiple aspects
Low	(1) Nonnative plant cover 6 - 25%, or (2) Recent disturbance within >10% of habitat area	25 or less	< 500	>10% (High Loss)	(1) Moderate or high radiation load, and (2) One aspect

6.3 Scenario 1 – Conservation

Resiliency under Scenario 1 – Under this scenario, we anticipate that Frisco buckwheat, Ostler's peppergrass, and Frisco Clover populations will be stable and similar to the current condition due to the cessation of stone mining and no new precious metal exploration and mining occurring in population areas (Figure 14; Figure 15; and Figure 16; ; Table 26; Table 27; and Table 28). We anticipate population habitat and demographic factors will remain the same as the current condition. When we considered climate change resiliency, the overall condition of each species' populations remained the same as the current condition with the exception of the Frisco clover Lime Mountain population which went from Good to Moderate condition. Good and Moderate resiliency likely provide plant populations the ability to withstand stochastic events such as drought or wildfire. Without additional habitat loss, there is the potential for Frisco buckwheat and Ostler's peppergrass to recolonize existing stone mine disturbance areas where suitable soils are present and a sufficient seed source is provided from remaining occupied habitat.

Table 26. Future Condition of Frisco buckwheat - Conservation Scenario.

Population	Habitat Factors		Demographic Factors	Habitat Loss Category	Climate Change Resilience	Overall Future Condition (Resiliency)
	Habitat Quality	Habitat Area	Population Size			
Grampian Hill	Good	Good	Good	Good	Moderate	Good
Cupric Mine	Good	Moderate	Moderate	Low	Moderate	Moderate
San Francisco	Good	Good	Good	Moderate	Moderate	Good

Table 27. Future Condition of Ostler's peppergrass - Conservation Scenario.

Population	Habitat Factors		Demographic Factors	Habitat Loss Category	Climate Change Resilience	Overall Future Condition (Resiliency)
	Habitat Quality	Habitat Area	Population Size			
Grampian Hill	Good	Good	Moderate	Good	Good	Good
Cupric Mine	Good	Moderate	Moderate	Low	Moderate	Moderate
San Francisco	Good	Moderate	Good	Good	Moderate	Good

Table 28. Future Condition of Frisco clover - Conservation Scenario.

Population	Habitat Factors		Demographic Factors	Habitat Loss Category	Climate Change Resilience	Overall Future Condition (Resiliency)
	Habitat Quality	Habitat Area	Population Size			
Blue Mountain	Good	Low	Low	Good	Low	Moderate
Grampian Hill	Good	Moderate	Good	Good	Good	Good
San Francisco	Good	Moderate	Moderate	Good	Moderate	Good
Lime Mountain	Good	Low	Moderate	Good	Moderate	Moderate
Tunnel Springs Mountains	Good	Good	Moderate	Good	Moderate	Good
Wah Wah Mountains	Good	Good	Moderate	Good	Moderate	Good

Redundancy under Scenario 1 – Under this scenario, we anticipate the maintenance of all existing populations of Frisco buckwheat, Ostler's peppergrass, and Frisco Clover throughout their current range. Levels of redundancy will remain low for all three species and the same as the historical redundancy. The three species will continue to have the maximum number of populations spread across their ranges and on different topographic features which may provide the ability to withstand more localized catastrophic events (wildfire, soil slumping), and may provide a limited ability to withstand range-wide catastrophic events (drought).

Representation under Scenario 1 – Under this scenario, levels of representation will remain low and be similar to what the species has currently. The predicted distribution is the same as the historical and current distributions with similar levels of genetic diversity and connectivity among populations.

Summary of Scenario 1 – Under this scenario, we anticipate the maintenance of all existing populations of Frisco buckwheat, Ostler's peppergrass, and Frisco Clover throughout their current range. This is due to the cessation of the two main stressors, stone mining and precious metal exploration and mining, in population areas under this scenario. Our evaluation of climate change resiliency did not change the overall condition of populations with the exception of the Frisco clover Lime Mountain population which went from good to moderate condition. We do not anticipate any significant changes in population trends or habitat conditions (i.e., increase in nonnative invasive species) during this time period because the two mining stressors are no longer impacting the three species.

6.4 Scenario 2 – Low to Moderate Level Precious Metal Exploration and Mining

Resiliency under Scenario 2 – Under this scenario, we predict that Frisco buckwheat, Ostler's peppergrass, and Frisco clover populations will be stable and similar to the current condition for precious metal exploration and mining (Figure 17; Figure 18; Table 29; Table 30; Table 31) due to the low impact of future exploration in plant populations and the location of moderate levels of precious metal mining outside of plant populations.

The main impact of this scenario to the three plant populations would be a reduction in habitat quality (Good to Moderate) of the Grampian Hill population for all three species as a result of exploration activities. This reduction in habitat quality does not change the overall Good condition of the Grampian Hill population for the three plant species. Even with more degraded habitat quality conditions that result in a Low habitat quality category, an overall Good condition is maintained for the Grampian Hill populations because there are three remaining categories in Good condition for each species (Appendix A).

With low amounts of habitat loss, there is the potential for Frisco buckwheat and Ostler's peppergrass to recolonize future precious metal exploration disturbance areas because suitable soils are present and a sufficient seed source is provided from remaining occupied habitat. We assumed future exploration would not result in greater than 5 percent habitat loss (Good condition category; Table 25). This is a reasonable assumption based on negligible past impacts to plant populations from precious metal exploration. If future precious metal exploration and mining results in more habitat loss than what we assumed for this scenario, the overall Grampian Hill population condition for the three species would be reduced to a Moderate category. The combined impact of additional habitat loss (Moderate or Low category) and reduced habitat quality (Moderate or Low category) would still result in an overall Moderate population condition for the Grampian Hill populations as long as there is no reduction in the population size and habitat area categories. We assumed no future impacts would result at the Old Quarry where the majority of Frisco buckwheat and Ostler's peppergrass individuals occur (Copper Gulch subpopulations of the San Francisco populations).

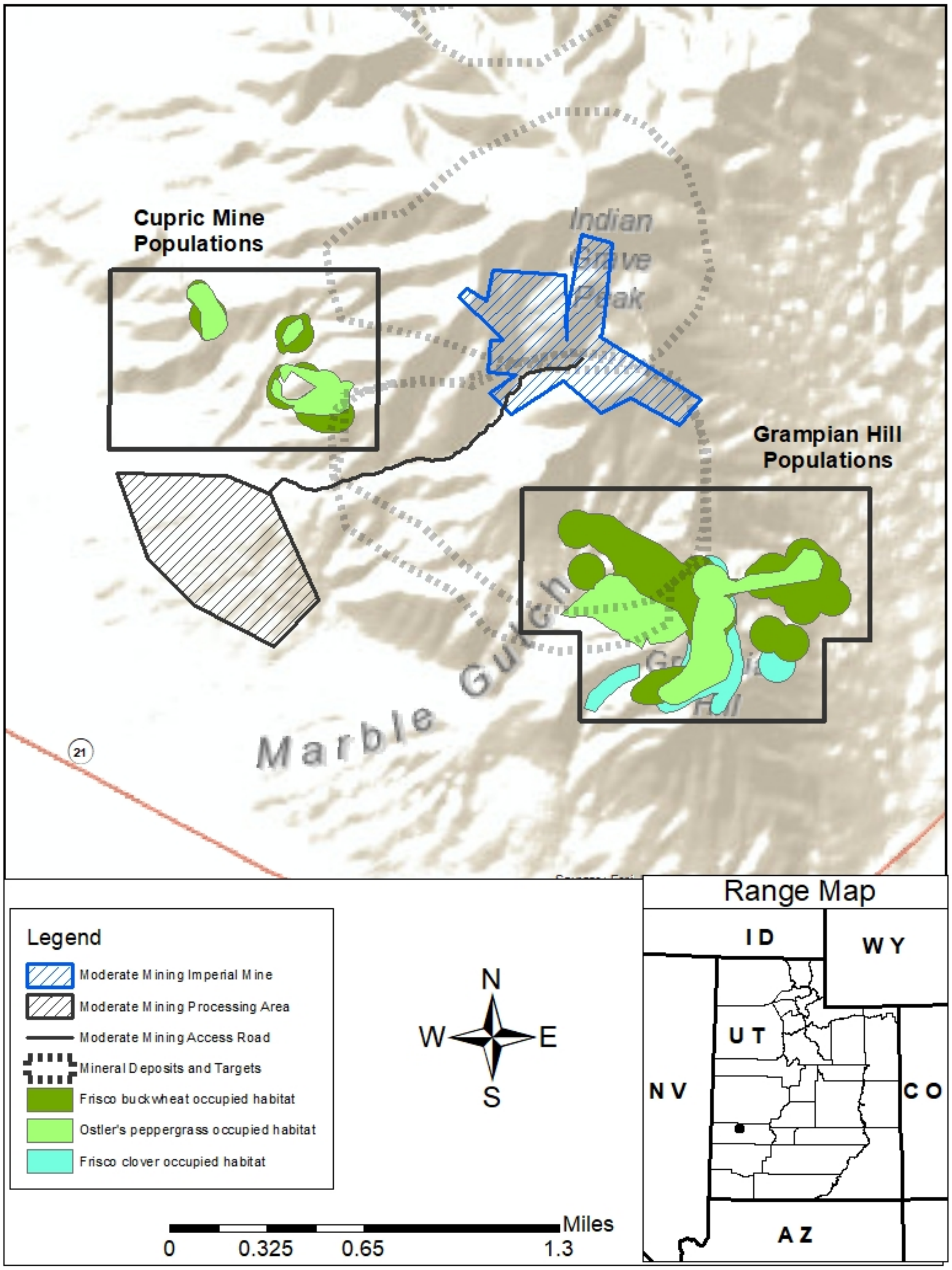

Figure 17. Low to Moderate Level Precious Metal Exploration and Mining Scenario at the Imperial Mine for Frisco buckwheat, Ostler's peppergrass, and Frisco clover near Grampian Hill and Cupric Mine populations. There is considerable uncertainty regarding where actual disturbances could be for future mining and processing. Actual disturbance could reasonably be expected to occur within these areas.

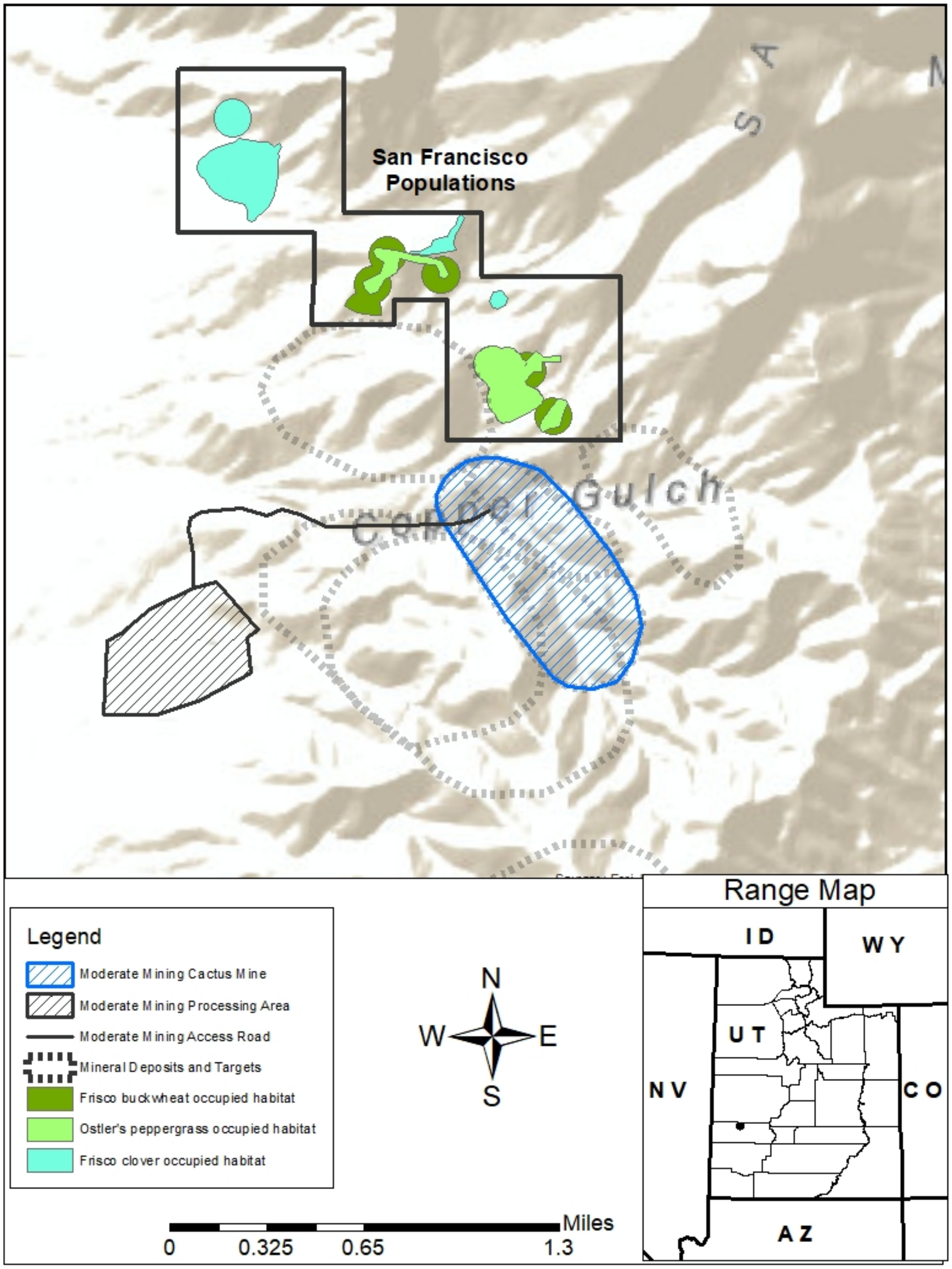

Figure 18. Low to Moderate Level Precious Metal Exploration and Mining Scenario at the Cactus Mine for Frisco buckwheat, Ostler's peppergrass, and Frisco clover near San Francisco populations. There is considerable uncertainty regarding where actual disturbances could be for future mining and processing. Actual disturbance could reasonably be expected to occur within these areas.

Table 29. Future Condition of Frisco buckwheat –Low to Moderate Level Precious Metal Exploration and Mining Scenario.

Population	Habitat Factors		Demographic Factors	Habitat Loss Category	Climate Change Resilience	Overall Future Condition (Resiliency)
	Habitat Quality	Habitat Area	Population Size			
Grampian Hill	Moderate	Good	Good	Good	Moderate	Good
Cupric Mine	Good	Moderate	Moderate	Low	Moderate	Moderate
San Francisco	Good	Good	Good	Moderate	Moderate	Good

Table 30. Future Condition of Ostler's peppergrass –Low to Moderate Level Precious Metal Exploration and Mining Scenario.

Population	Habitat Factors		Demographic Factors	Habitat Loss Category	Climate Change Resilience	Overall Future Condition (Resiliency)
	Habitat Quality	Habitat Area	Population Size			
Grampian Hill	Moderate	Good	Moderate	Good	Good	Good
Cupric Mine	Good	Moderate	Moderate	Low	Moderate	Moderate
San Francisco	Good	Moderate	Good	Good	Moderate	Good

Table 31. Future Condition of Frisco clover –Low to Moderate Level Precious Metal Exploration and Mining Scenario.

Population	Habitat Factors		Demographic Factors	Habitat Loss Category	Climate Change Resilience	Overall Future Condition (Resiliency)
	Habitat Quality	Habitat Area	Population Size			
Blue Mountain	Good	Low	Low	Good	Low	Moderate
Grampian Hill	Moderate	Moderate	Good	Good	Good	Good
San Francisco	Good	Moderate	Moderate	Good	Moderate	Good
Lime Mountain	Good	Low	Moderate	Good	Moderate	Moderate
Tunnel Springs Mountains	Good	Good	Moderate	Good	Moderate	Good
Wah Wah Mountains	Good	Good	Moderate	Good	Moderate	Good

When we considered climate change resiliency, the overall condition of each species' populations remained the same as the current condition with the exception of the Frisco clover Lime Mountain population which went from Good to Moderate condition.

Redundancy under Scenario 2 – Under this scenario, we anticipate the maintenance of all existing populations of Frisco buckwheat, Ostler's peppergrass, and Frisco Clover throughout their current range. Levels of redundancy will remain low for all three species and be the same as historical redundancy. The three species will continue to have the maximum number of populations spread across their ranges and on different topographic features (section 3.1, Range and Distribution) which may provide the ability to withstand more localized catastrophic events (wildfire, soil slumping), and may provide a limited ability to withstand range-wide catastrophic events (drought).

Representation under Scenario 2 – Under this scenario, levels of representation will remain low, but similar to what the species has currently. The predicted distribution is the same as the historical and current distributions with similar levels of genetic diversity and connectivity among populations.

Uncertainty Discussion – We are uncertain about the extent of impacts from precious metal exploration and mining activities in High Potential populations (Frisco buckwheat, Ostler's peppergrass, and Frisco clover Grampian Hill populations; Frisco buckwheat and Ostler's peppergrass San Francisco populations; Table 10). For this scenario, we assumed low impacts from exploration activities and avoidance of plant populations from future mining. These assumptions are similar to historical impacts in plant populations. However, future impacts may result in higher levels of habitat degradation and habitat loss if a large deposit(s) is located and mined in or near the Grampian Hill and San Francisco populations of the three species. We evaluate a worst-case future mining situation as described in the High Level Stone and Precious Metal Mining Scenario. We identify conservation measures to improve the population condition based on our future condition metrics (Table 25) in Appendix F.

Summary of Scenario 2 – Under this scenario, we anticipate the maintenance of all existing populations of Frisco buckwheat, Ostler's peppergrass, and Frisco Clover throughout their current range. This is due to a low precious metal exploration and moderate mining future scenario that results in minor impacts to the Grampian Hill population of the three plant species. Our evaluation of climate change resiliency did not change the overall condition of populations with the exception of the Frisco clover Lime Mountain population which went from Good to Moderate condition. We do not anticipate any significant changes in population trends or habitat area for any other plant populations.

6.5 Scenario 3 – Moderate Level Stone Mining

Resiliency under Scenario 3 – Under this scenario, the main stressor affecting overall condition is stone mining. Where the three active stone mines occur, Frisco buckwheat, Ostler's peppergrass, and Frisco clover will decline and be worse than the current condition due to the predicted impacts to population size and habitat loss from the extent of stone mining within populations (Frisco buckwheat Cupric Mine; Ostler's peppergrass Cupric Mine; Frisco clover Blue Mountain) and subpopulations (Frisco buckwheat Indian Queen subpopulation in the San Francisco population; Ostler's peppergrass Indian Queen subpopulation in the San Francisco population) (Figure 19; Figure 20; Figure 21; Table 32; Table 33; Table 34). Remaining plant populations will have a future condition identical to the Conservation Scenario.

Stone mining impacts are greater for smaller populations (Frisco buckwheat and Ostler's peppergrass at Cupric Mine; Frisco clover at Blue Mountain) than larger populations (Frisco buckwheat and Ostler's peppergrass at San Francisco Mountains) (Table 25). The Frisco clover Blue Mountain population is most sensitive to stone mining impacts because it already is small in population size and habitat area. Therefore, the overall population condition would decline with Moderate habitat loss (greater than 5 percent). The Frisco buckwheat and Ostler's peppergrass Cupric Mine population conditions would decline after a future loss of 21 ac (8.5 ha) and 4.5 ac (1.8 ha), respectively (Appendix A). The San Francisco populations of Frisco buckwheat and Ostler's peppergrass are less sensitive to habitat loss at the Indian Queen subpopulations because there is sufficient habitat area and population size remaining at the Old Quarry (Copper Gulch subpopulations) to support the overall population condition.

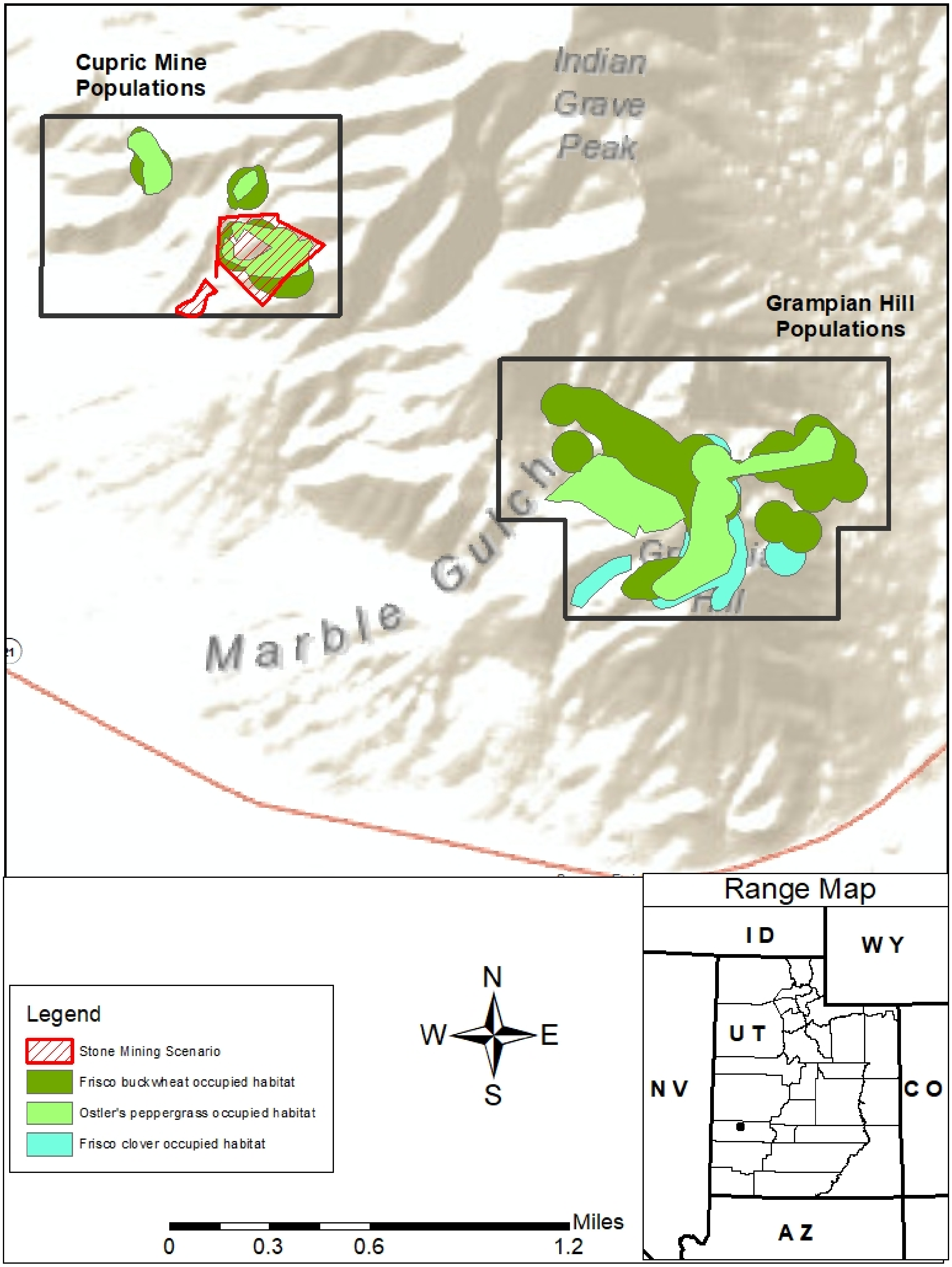

Figure 19. Moderate Level Stone Mining Scenario for Frisco buckwheat, Ostler's peppergrass and Frisco clover at the Grampian Hill and Cupric Mine populations.

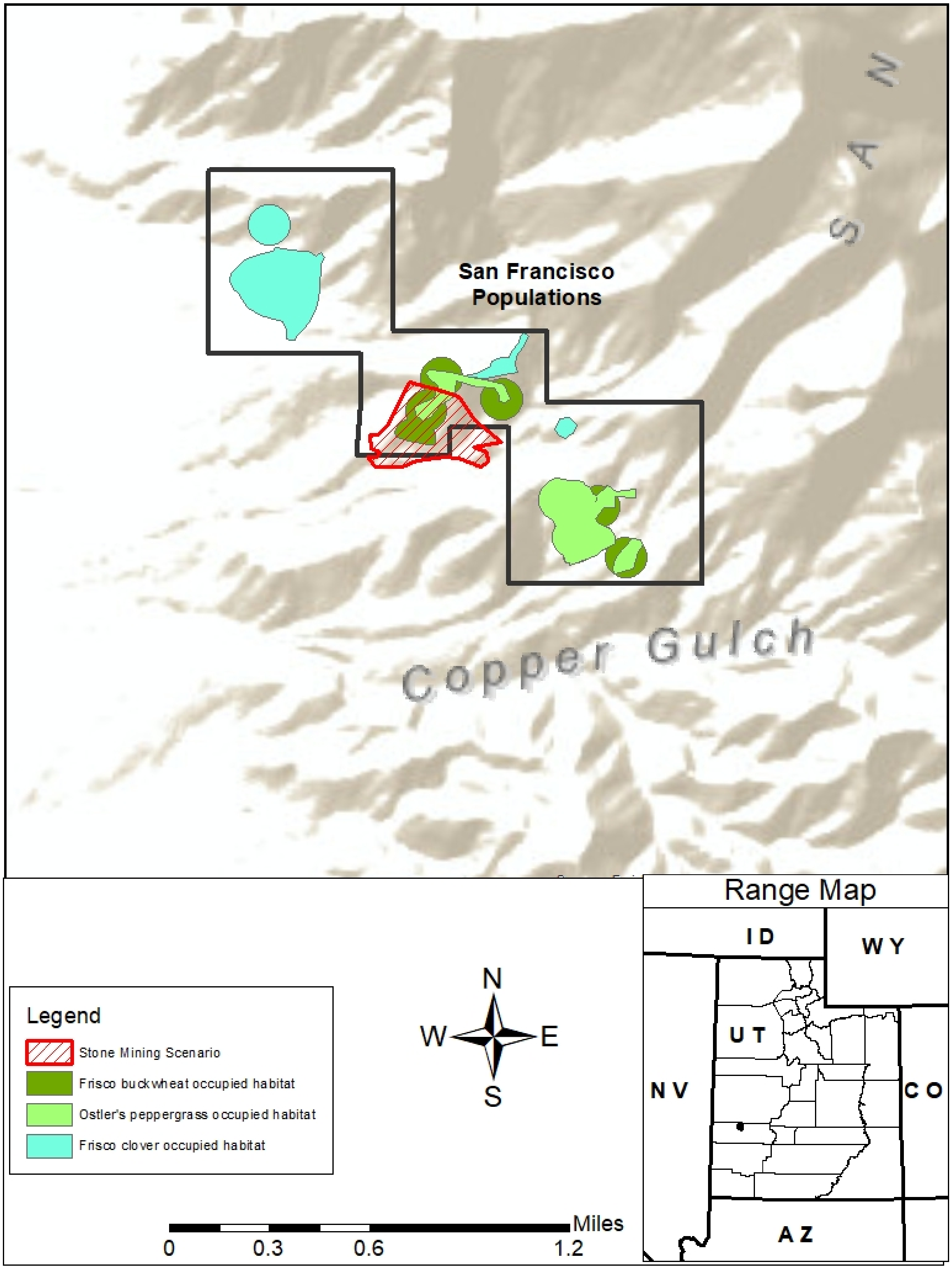

Figure 20. Moderate Level Stone Mining Scenario for the Frisco buckwheat, Ostler's peppergrass, and Frisco clover San Francisco populations.

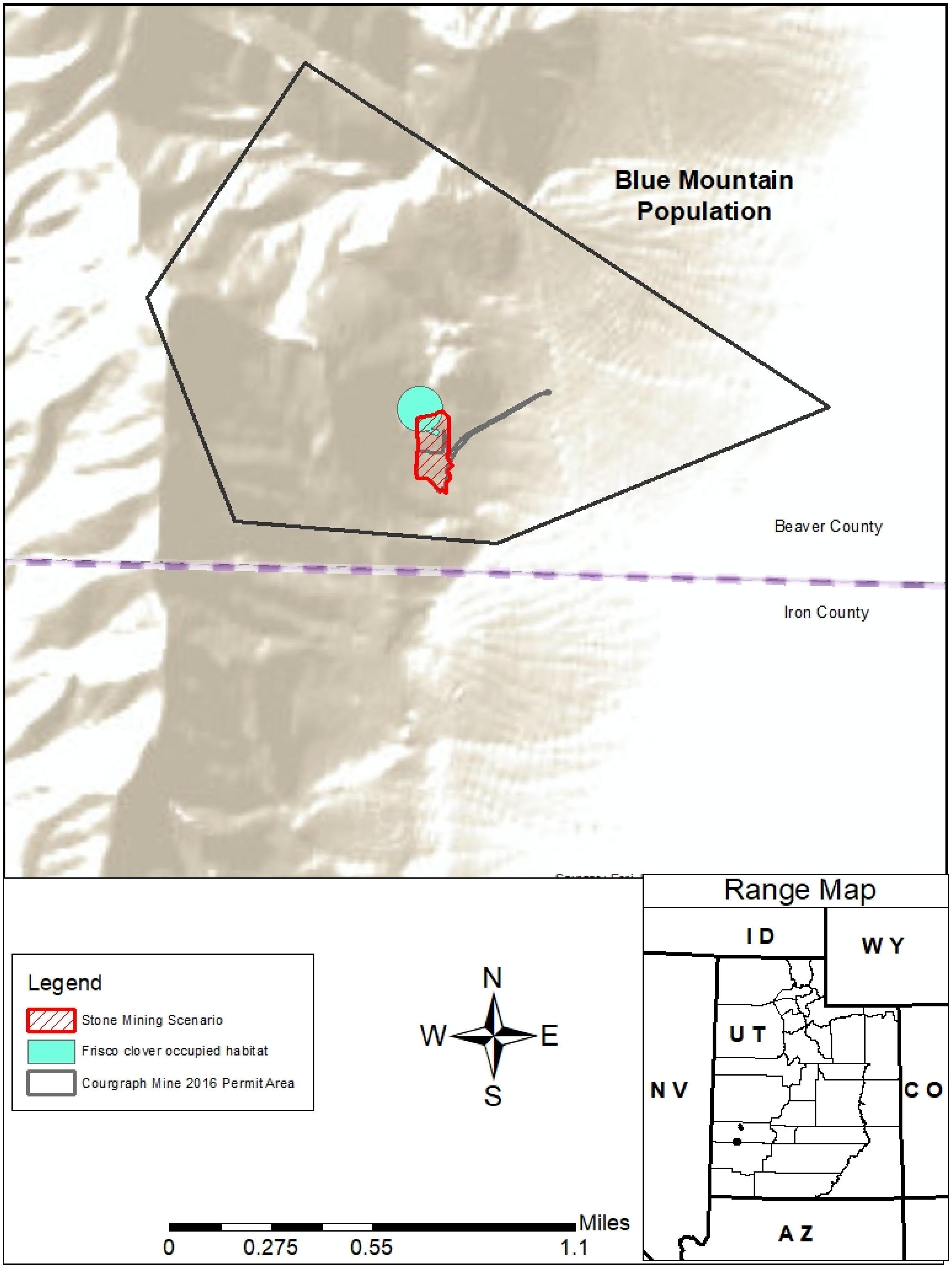

Figure 21. Moderate Level Stone Mining Scenario for Frisco clover at the Blue Mountain population.

Table 32. Future Condition of Frisco buckwheat – Moderate Level Stone Mining Scenario.

Population	Habitat Factors		Demographic Factors	Habitat Loss Category	Climate Change Resilience	Overall Future Condition (Resiliency)
	Habitat Quality	Habitat Area	Population Size			
Grampian Hill	Good	Good	Good	Good	Moderate	Good
Cupric Mine	Good	Low	Low	Low	Moderate	Low
San Francisco	Good	Moderate	Good	Low	Moderate	Moderate

Table 33. Future Condition of Ostler's peppergrass – Moderate Level Stone Mining Scenario.

Population	Habitat Factors		Demographic Factors	Habitat Loss Category	Climate Change Resilience	Overall Future Condition (Resiliency)
	Habitat Quality	Habitat Area	Population Size			
Grampian Hill	Good	Good	Moderate	Good	Good	Good
Cupric Mine	Good	Low	Low	Low	Moderate	Low
San Francisco	Good	Moderate	Good	Low	Moderate	Moderate

Table 34. Future Condition of Frisco clover – Moderate Level Stone Mining Scenario.

Population	Habitat Factors		Demographic Factors	Habitat Loss Category	Climate Change Resilience	Overall Future Condition (Resiliency)
	Habitat Quality	Habitat Area	Population Size			
Blue Mountain	Good	Low	Low	Low	Low	Low
Grampian Hill	Good	Moderate	Good	Good	Good	Good
San Francisco	Good	Moderate	Moderate	Good	Moderate	Good
Lime Mountain	Good	Low	Moderate	Good	Moderate	Moderate
Tunnel Springs Mountains	Good	Good	Moderate	Good	Moderate	Good
Wah Wah Mountains	Good	Good	Moderate	Good	Moderate	Good

We lack plant distribution data within population and subpopulation areas for a more detailed evaluation of population size impacts for this scenario. Our assumptions for population size impacts to the small populations are reasonable given their current population sizes, and our assumption does not change the overall condition of the Frisco buckwheat and Ostler's peppergrass San Francisco populations due to the large number of individuals at the Old Quarry (Copper Gulch subpopulations). In addition, overall population condition does not change if we exclude population size from our analysis or if we predict more extensive stone mining impacts at the three stone mines that result in the loss of all plants at these locations. We assumed this worst case stone mining situation in the High Level Stone and Precious Metal Mining Scenario (section 6.6, Scenario 4). We also provide more details about how to improve population condition scores in the Uncertainty and Population Score Discussion section, below. The climate change resilience of populations did not affect the overall condition of the three plant populations with the stone mining stressor.

Predicted reductions in population size and habitat area make Frisco buckwheat and Ostler's peppergrass more vulnerable to stochastic events. For the Frisco clover Blue Mountain population, the small population size and habitat area already make this population vulnerable to stochastic events.

Redundancy under Scenario 3 – Under this scenario, we anticipate the maintenance of all existing populations of Frisco buckwheat, Ostler's peppergrass, and Frisco Clover throughout their current range since stone mining impacts do not result in the entire loss of populations and subpopulations at current stone mines. Levels of redundancy will remain low for all three species and thus are the same as the current redundancy.

Representation under Scenario 3 – Although we did not have detailed distribution data to predict the number of plants lost to stone mining, under this scenario and for all species we predict a reduction in representation due to the loss of individuals. Impacts to representation will depend on the number of individuals lost to stone mining, and the associated reduction in the species' adaptive capacity to tolerate future climate and habitat conditions.

Uncertainty Discussion – We have uncertainty about the extent of future stone mining impacts to the Cupric Mine and San Francisco populations of Frisco buckwheat and Ostler's peppergrass, and the Blue Mountain population of Frisco clover. Here we discuss the uncertainty for plant populations. We identify conservation measures to improve the population condition based on our future condition metrics (Table 25) with less extensive future stone mining in Appendix F.

Although we recognize that there are no regulatory mechanisms or voluntary agreements to prevent the loss of the populations and subpopulations with the stone mining stressor, we assumed stone mining impacts would not result in their complete loss because future stone mining would not be that extensive. It is also reasonable to assume that all occupied habitat for the three species consists of the high quality marble stone or landscaping rock that is of interest to the operator. The slow rate of stone mining and permit expansion since 2000 suggests a slow rate of future stone mining at the Southern White/Mountain Rose and Courgraph mines. The partially reclaimed status of the Indian Queen large stone mine operation and the lack of excavation since 2006 suggests lower likelihood of future stone mining than the other two mines. If future mining does not resume at the Indian Queen stone mine, the Frisco buckwheat and Ostler's peppergrass San Francisco populations will remain in Good condition.

The State UDOGM commented that a realistic future stone mining scenario would include continued stone mining at active stone mines where the operator would reclaim portions of the mine prior to mine expansion in order to maintain a small mine permit status (Brinton 2018c, p. 1). This would enable the operator to avoid surveys and an environmental assessment required for large mine permits (section 4.2, Stone Mining). We assumed future stone mining would not occur at the Old Quarry located in the Copper Gulch subpopulations of Frisco buckwheat and Ostler's peppergrass. If future stone mining does occur at the Old Quarry, we will need to re-evaluate the future condition of the San Francisco populations. Future stone mining impacts would be high at the Old Quarry because this location contains the majority of the individuals for both species. There is the potential for recolonization of both species on reclaimed soils, particularly if future mining occurs at a slow pace, but there is considerable uncertainty regarding the success of recolonization and reclamation methods to support accelerated recolonization that minimizes stone mining impacts to both species.

Summary of Scenario 3 – Under this scenario, the main stressor affecting overall condition is stone mining. Two populations of Frisco buckwheat and Ostler's peppergrass and one population of Frisco clover are located at or near active stone mines. There is uncertainty regarding the extent of mining impacts; however, we predict that for these populations conditions will decline due to population size reductions, habitat area reductions, and habitat loss. We predict an overall Low condition for the Cupric Mine population of Frisco buckwheat and Ostler's peppergrass, and also the Blue Mountain population of Frisco clover. These populations are expected to be in decline and thus will not be resilient to stochastic events under this scenario. We predict an overall Moderate condition for the San Francisco population of Frisco buckwheat and Ostler's peppergrass based on the retention of plants and habitat area at the Old Quarry. Redundancy is not predicted to decrease under this scenario. Impacts to representation for all three species depend on how many individual plants are lost to stone mining in populations. Population condition for all other plant populations are identical to the Conservation Scenario.

6.6 Scenario 4 – High Level Stone and Precious Metal Mining

Resiliency under Scenario 4 – Under this scenario, we predict that Frisco buckwheat, Ostler's peppergrass, and Frisco clover populations with one or both mining stressors will be declining and worse than the current condition (Figure 22; Figure 23; Figure 24; Table 35; Table 36; Table 37). The main stressors affecting overall condition are stone mining and precious metal exploration and mining. We predict the loss of the populations (Frisco buckwheat at Cupric Mine; Ostler's peppergrass at Cupric Mine; Frisco clover at Blue Mountain) and subpopulations (Frisco buckwheat Indian Queen subpopulation in the San Francisco population; Ostler's peppergrass Indian Queen subpopulation in the San Francisco population) that contain active stone mines as a result of habitat loss and slope subsidence under this scenario. This is considered a worst-case scenario for stone mining. Impacts to resiliency from stone mining are greater for Frisco buckwheat than Ostler's peppergrass and Frisco clover based on anticipated population size reductions. The predicted loss is equivalent to 27 percent, 14 percent, and 2 percent of Frisco buckwheat, Ostler's peppergrass, and Frisco clover total populations, respectively.

Precious metal exploration and mining impacts are greatest at Grampian Hill and result in the Low condition of this population for the three plant species. Precious metal exploration and mining impacts alone do not contribute to the reduced population condition of the Cupric Mine and San Francisco populations of Frisco buckwheat and Ostler's peppergrass. Stone mining is the major influence of population condition for these two populations, and the Frisco clover Blue Mountain population. We assumed no future impacts at the Old Quarry where the majority of Frisco buckwheat and Ostler's peppergrass individuals occur (Copper Gulch subpopulations).

We are uncertain about the extent of impacts from precious metal exploration and mining activities in High Potential populations (Frisco buckwheat, Ostler's peppergrass, and Frisco clover Grampian Hill populations; Frisco buckwheat and Ostler's peppergrass San Francisco populations; Table 10). For this scenario, we assumed extensive impacts that are similar to the estimates of mining disturbance provided by the BLM (4.1, Precious Metal Exploration and Mining). However, future impacts may result in low levels of habitat degradation and negligible habitat loss (similar to historical impacts as described in the Low to Moderate Level Precious Metal Exploration and Mining Scenario) if no large deposit(s) is located and mined in or near the Grampian Hill and San Francisco populations of the three species. Nevertheless, all three populations of Frisco buckwheat and Ostler's peppergrass occur within active stone mines and our precious metal evaluation area. We predict the loss of self-sustaining Frisco buckwheat and Ostler's peppergrass populations if extensive precious metal exploration and mining impacts occur in combination with extensive stone mining impacts. Even if precious metal exploration and mining impacts are less extensive, we predict declines in resiliency for habitat at active stone mines based on predicted extensive impacts to habitat area and habitat loss.

We predict habitat conditions will deteriorate in populations affected by the two mining stressors and the increased presence of nonnative invasive species under this scenario. Predicted reductions in habitat quality, habitat quantity, and population size make Frisco buckwheat and Ostler's peppergrass more vulnerable to stochastic events. For Frisco clover, the resiliency of populations remains the same as the Conservation Scenario with the exception of the Grampian Hill population, the largest population of the species. The climate change resilience of populations did not negatively affect the overall condition of populations with the exception of the Frisco clover Lime Mountain population which went from Good to Moderate condition.

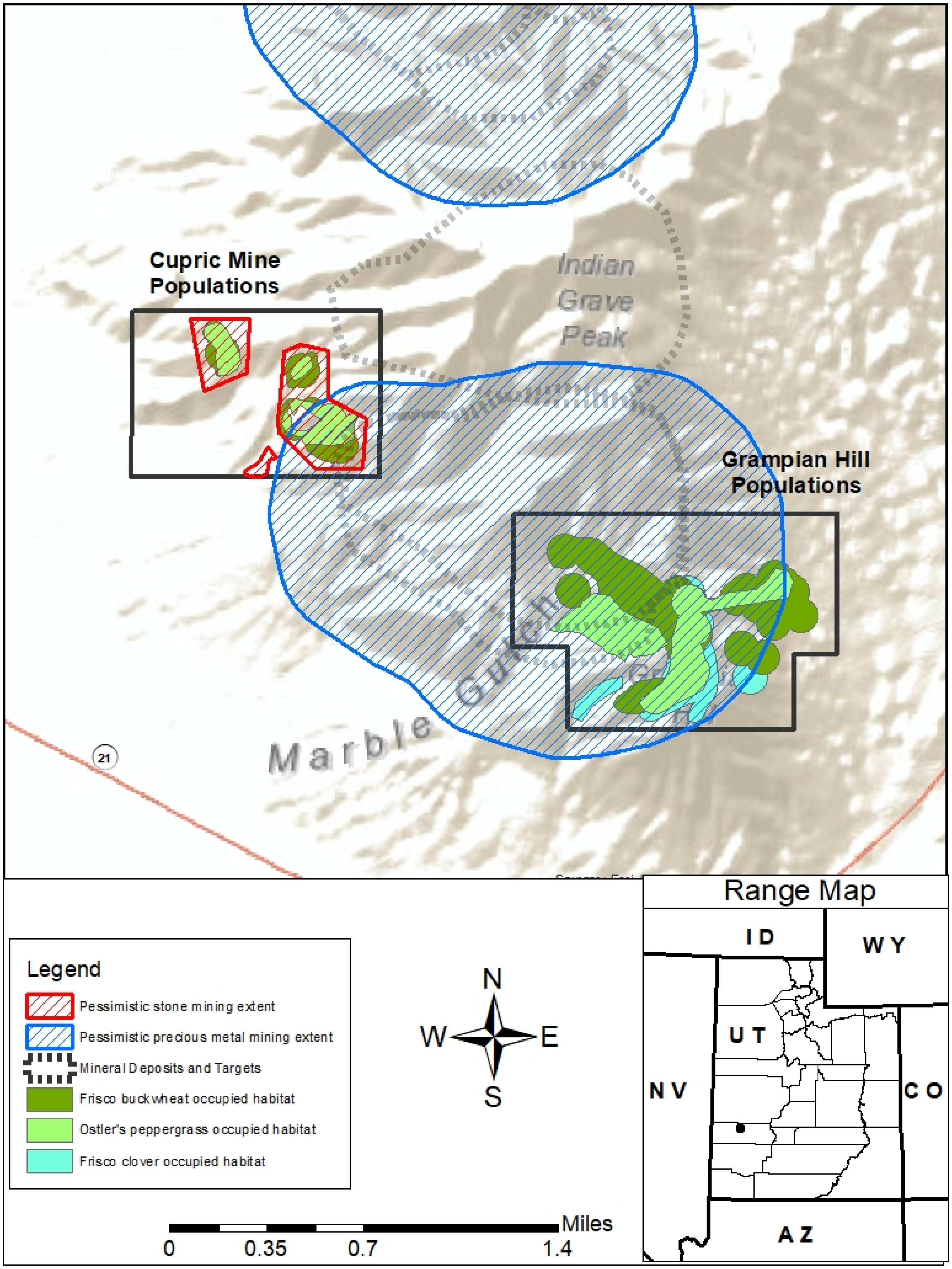

Figure 22. High Level Stone and Precious Metal Mining Scenario for Frisco buckwheat, Ostler's peppergrass, and Frisco clover near Grampian Hill and Cupric Mine populations.

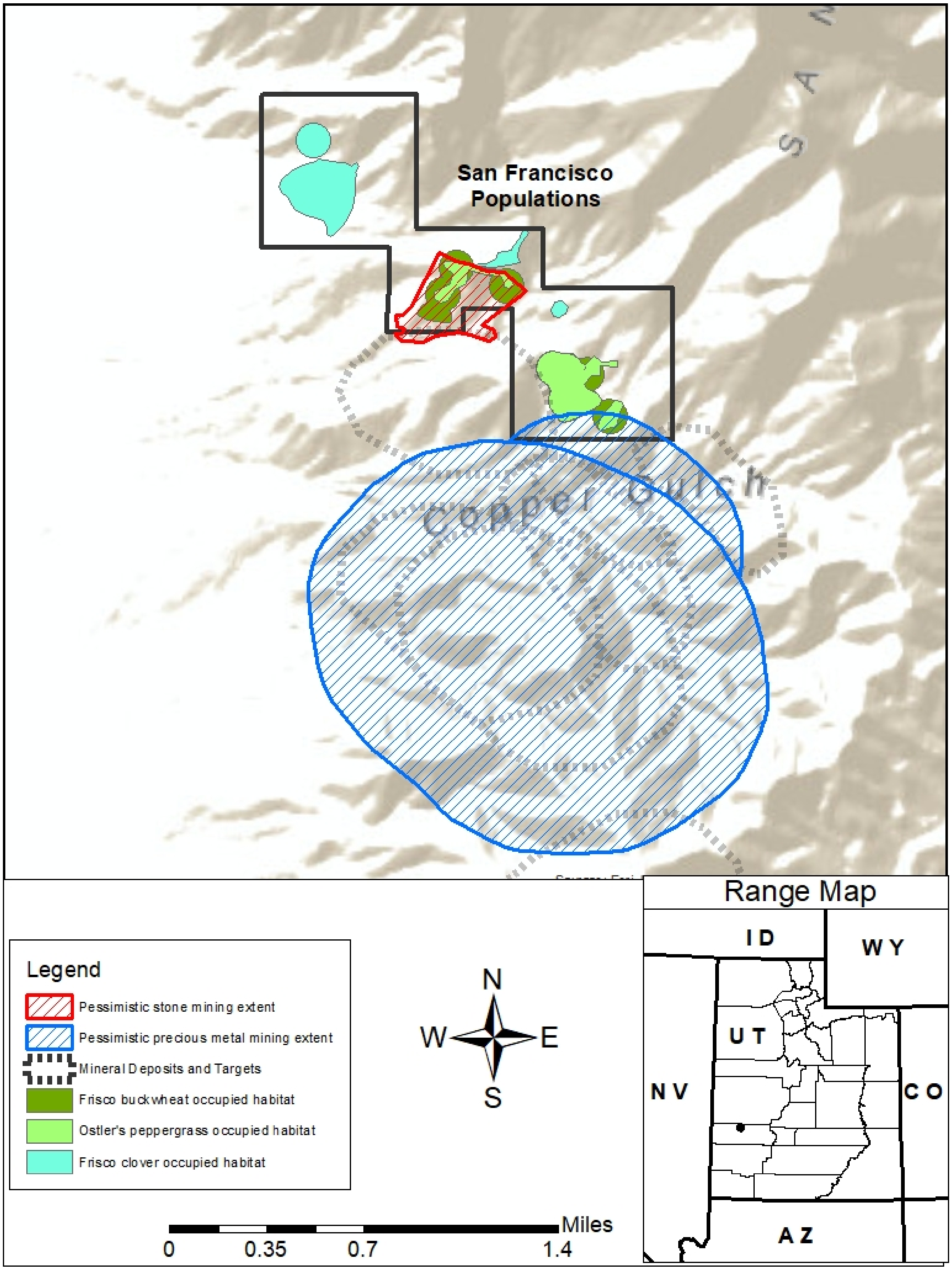

Figure 23. High Level Stone and Precious Metal Mining Scenario for Frisco buckwheat, Ostler's peppergrass, and Frisco clover near San Francisco populations.

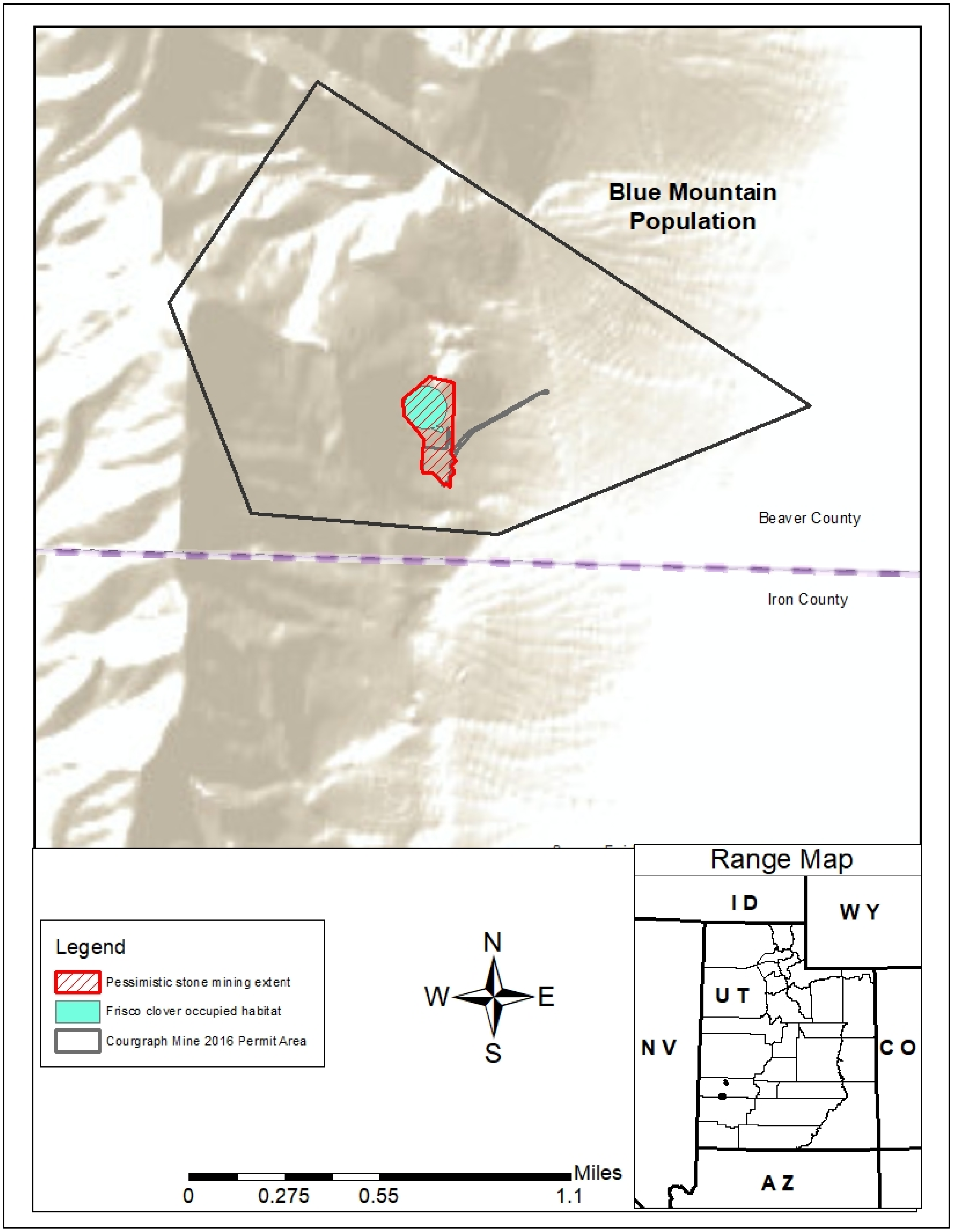

Figure 24. High Level Stone and Precious Metal Mining Scenario for Frisco clover near the Blue Mountain population.

Table 35. Future Condition of Frisco buckwheat - High Level Stone and Precious Metal Mining Scenario.

Population	Mining Stressors	Habitat Factors		Demographic Factors	Habitat Loss Category	Climate Change Resilience	Overall Future Condition (Resiliency)
		Habitat Quality	Habitat Area	Population Size			
Grampian Hill	Precious metal exploration and mining	Low	Low	Unknown	Low	Moderate	Low
Cupric Mine	Expansion of stone mining; precious metal exploration and mining	Low	Low	Low	Low	Moderate	Low
San Francisco	Expansion of stone mining at Indian Queen subpopulation; Precious metal exploration and mining impacts at Copper Gulch subpopulation	Low	Moderate	Good	Low	Moderate	Moderate

Table 36. Future Condition of Ostler's peppergrass - High Level Stone and Precious Metal Mining Scenario.

Population	Mining Stressors	Habitat Factors		Demographic Factors	Habitat Loss Category	Climate Change Resilience	Overall Future Condition (Resiliency)
		Habitat Quality	Habitat Area	Population Size			
Grampian Hill	Precious metal mining	Low	Low	Unknown	Low	Good	Low
Cupric Mine	Expansion of stone mining; precious metal exploration and mining	Low	Low	Low	Low	Moderate	Low
San Francisco	Expansion of stone mining at Indian Queen subpopulation; Precious metal exploration and mining impacts at Copper Gulch subpopulation	Low	Moderate	Good	Low	Moderate	Moderate

Table 37. Future Condition of Frisco clover - High Level Stone and Precious Metal Mining Scenario.

Population	Mining Stressors	Habitat Factors		Demographic Factors	Habitat Loss Category	Climate Change Resilience	Overall Future Condition (Resiliency)
		Habitat Quality	Habitat Area	Population Size			
Blue Mountain	Expansion of stone mining	Low	Low	Low	Low	Low	Low
Grampian Hill	Precious metal exploration and mining	Low	Low	Unknown	Low	Good	Low
San Francisco	No mining	Good	Moderate	Moderate	Good	Moderate	Good
Lime Mountain	No mining	Good	Low	Moderate	Good	Moderate	Moderate
Tunnel Springs Mountains	No mining	Good	Good	Moderate	Good	Moderate	Good
Wah Wah Mountains	No mining	Good	Good	Moderate	Good	Moderate	Good

Redundancy under Scenario 4 – Under this scenario, we predict a reduction in redundancy for all three plant species. We predict the loss of three plant populations (Frisco buckwheat at Cupric Mine; Ostler's peppergrass at Cupric Mine; Frisco clover at Blue Mountain) to extensive stone mining from a combination of habitat loss and slope subsidence. We predict the Grampian Hill populations of all three species will be in Low condition as a result of extensive precious metal exploration and mining. If precious metal exploration and mining is less extensive, impacts to redundancy are less severe and remain at the level predicted from extensive stone mining impacts. Under this scenario and for all species, a reduction in the number and distribution of healthy populations across each species' range reduces each species' ability to buffer against localized (wildfire, soil slumping), and range-wide (drought) catastrophic events.

Representation under Scenario 4 – Under this scenario and for all species, we predict a reduction in representation as a result of stone mining and precious metal mining. Stone mining alone is predicted to result in the loss of 27 percent, 14 percent, and 2 percent of Frisco buckwheat, Ostler's peppergrass, and Frisco clover total populations, respectively. Impacts to representation increase in combination with precious metal exploration and mining, and reduce the species' adaptive capacity to tolerate future climate and habitat conditions.

Uncertainty Discussion – We have uncertainty about the extent of future precious metal exploration and mining impacts to Grampian Hill populations and stone mining impacts to Cupric Mine, and San Francisco populations of Frisco buckwheat and Ostler's peppergrass, and the Grampian Hill, and Blue Mountain populations of Frisco clover. Here we discuss the uncertainty for the populations. We identify conservation measures to improve the population condition based on our future condition metrics (Table 25), and with less extensive future stone mining and precious metal exploration and mining in Appendix F.

Frisco buckwheat, Ostler's peppergrass and Frisco clover Grampian Hill populations **–** We are uncertain that future precious metal exploration and mining will result in the extensive impacts to habitat area and habitat quality that we evaluate in this scenario. The potential for future mining to impact these populations is strongly dependent on the mineral development potential of the Accrington and Perseverance targets which are currently under exploration. Additional exploratory drilling is needed to document the size and extent of the mineral targets and results are expected as early as late-summer of 2018. If these two targets do not have development potential, it is unlikely that precious metal mining will impact the Grampian Hill populations of the three species in the near future, and population condition scores would be identical to the Low and Moderate Precious Metal Exploration and Mining Scenario (section 6.4, Scenario 2).

Frisco buckwheat and Ostler's peppergrass Cupric Mine populations **–** We are uncertain that the entire Cupric Mine population of the two species will be lost to future stone mining and precious metal exploration and mining. The slow rate of stone mining and permit expansion since 2000 suggests a slower rate of future stone mining than what we include in our scenario. The State UDOGM commented that a more realistic future stone mining scenario would include continued stone mining at this population where the operator would reclaim portions of the mine prior to mine expansion in order to maintain a small mine permit status (Brinton 2018c, p.1). We discuss uncertainty in the Moderate Level Stone Mining Scenario (section 6.5, Scenario 3).

Frisco buckwheat and Ostler's peppergrass San Francisco populations **–** We are uncertain that the entire Indian Queen subpopulation of Frisco buckwheat and Ostler's peppergrass will be lost to future stone mining and slope subsidence. We are uncertain about the extent and impacts of precious metal exploration and mining in the populations. The partially reclaimed status of the Indian Queen large stone mine operation and the lack of excavation since 2006 suggests lower certainty of future stone mining than the other two stone mines (Southern White/ Mountain Rose; Courgraph), and a slow rate of future stone mining. We discuss uncertainty in the Moderate Level Stone Mining Scenario (section 6.5, Scenario 3).
Frisco clover Blue Mountain Population **–** We are uncertain that the entire Blue Mountain population of Frisco clover will be lost to future stone mining and slope subsidence. We discuss uncertainty in the Moderate Level Stone Mining Scenario (section 6.5, Scenario 3).

Summary of Scenario 4 – Under this scenario, the main stressors affecting overall condition are stone mining and precious metal exploration and mining that will continue to impact plant populations. There is uncertainty regarding the extent of mining impacts; however, we predict habitat conditions will deteriorate in populations affected by mining and the increased presence of nonnative invasive species under this scenario. We predict an overall Low condition for two Frisco buckwheat and Ostler's peppergrass populations (Grampian Hill and Cupric Mine) that are expected to be in decline and not resilient to stochastic events under this scenario. We predict an overall Moderate condition for the San Francisco population of Frisco buckwheat and Ostler's peppergrass based on the retention of a Moderate habitat acreage and a Good population size at the Old Quarry. All three populations of Frisco buckwheat and Ostler's peppergrass are predicted to occur within active stone mines and precious metal deposit areas. If precious metal mining impacts are extensive, we predict a high likelihood of extirpation for the two Frisco buckwheat and Ostler's peppergrass populations (Grampian Hill and Cupric Mine) in Low condition under this scenario. We predict a Low condition for the largest population of Frisco clover at Grampian Hill and the loss of the Blue Mountain population; remaining populations are in Good or Moderate condition. The climate change resilience of populations did not affect the overall condition of populations with the exception of the Frisco clover Lime Mountain population which went from Good to Moderate condition.

Chapter 7. Synopsis of Viability

Viability is the ability of a species to sustain populations over time. Species which exhibit high resiliency, redundancy, and representation are more viable than those that do not.

Frisco buckwheat, Ostler's peppergrass, and Frisco clover currently exhibit levels of resiliency, redundancy, and representation that allow populations to persist throughout each species' entire historic range. Populations of all three species are currently in Good or Moderate condition. The levels of redundancy and representation are similar to what they were historically. All three species persist despite some historical precious metal exploration and mining, recent stone mining, and intermittent drought conditions that have occurred in the western United States for the last 17 years.

The current persistence of Frisco buckwheat, Ostler's peppergrass, and Frisco clover is not a direct result of any ongoing conservation measures. Rather, the current condition is a direct result of the little to no habitat loss and degradation to-date in the populations. The ability of all three species to retain redundancy and maintain resilient populations to catastrophic environmental events is dependent upon high quality, intact habitat conditions that provide necessary nutritional and reproductive resources to enable the species to persist under extreme weather events.

We forecast the future viability of the species by predicting the responses of our populations to conditions under four future scenarios 20 years into the future (Table 38, Table 39, and Table 40). Based on the stressors and metrics evaluated in our analysis, the two stressors that impart the strongest influence on future condition are stone mining and precious metal exploration and mining. Nonnative invasive species occur at low or trace levels and are not expected to increase on their own, but would in conjunction with the two mining stressors. Climate change does not impart a strong influence on the future condition of populations.

The resiliency of Frisco buckwheat and Ostler's peppergrass are identical under all future scenarios because they share similar ranges, population distribution, exposure to stressors, and responses to stressors. Frisco clover has less exposure to stone mining and precious metal exploration and mining due to the species' larger range. Three populations of Frisco clover are not impacted and four populations are not predicted to be impacted by the two mining stressors. Our evaluation identified that precious metal exploration does not have a large influence on the resiliency of plant populations, precious metal mining has the largest influence on the resiliency of the three species' Grampian Hill populations, and stone mining has the largest influence on the resiliency of the Frisco buckwheat and Ostler's peppergrass Cupric Mine and San Francisco populations as well as the Frisco clover Blue Mountain population. Stone mining has a larger impact to resiliency for small plant populations (Frisco buckwheat and Ostler's peppergrass at Cupric Mine, and Frisco clover at Blue Mountain) than larger populations (Frisco buckwheat and Ostler's peppergrass at San Francisco).

Table 38. Summary of the Frisco buckwheat overall condition scores (Low, Moderate, Good) under the current scenario and four future scenarios. Metrics for evaluating current and future condition are identified in Table 17 and Table 25, respectively. (*There is greater exposure to stone mining and precious metal exploration and mining impacts under the High Level Stone and Precious Metal Mining Scenario).

Population	Estimated Population Size (Percent of Total Population)	Mining Stressors	Overall Current Condition (Resiliency)	Conservation Future Condition (Resiliency)	Low to Moderate Level Precious Metal Exploration and Mining Future Condition (Resiliency)	Moderate Level Stone Mining Future Condition (Resiliency)	High Level Stone and Precious Metal Mining Future Condition (Resiliency)
Grampian Hill	20,000 (26%)	Precious metal exploration and mining	Good	Good	Good	Good	Low
Cupric Mine	1,000 (1%)	Stone mining; Precious metal exploration and mining	Moderate	Moderate	Moderate	Low	Low
San Francisco	57,500 (73%)	Stone mining at Indian Queen subpopulation; Precious metal exploration and mining at Copper Gulch subpopulation*	Good	Good	Good	Moderate	Moderate

Table 39. Summary of the Ostler's peppergrass overall condition scores (Low, Moderate, Good) under the current scenario and four future scenarios. Metrics for evaluating current and future condition are identified in Table 17 and Table 25, respectively. (*There is greater exposure to stone mining and precious metal exploration and mining impacts under the High Level Stone and Precious Metal Mining Scenario).

Population	Estimated Population Size (Percent of Total Population)	Mining Stressors	Overall Current Condition (Resiliency)	Conservation Future Condition (Resiliency)	Low to Moderate Level Precious Metal Exploration and Mining Future Condition (Resiliency)	Moderate Level Stone Mining Future Condition (Resiliency)	High Level Stone and Precious Metal Mining Future Condition (Resiliency)
Grampian Hill	2,000 (5%)	Precious metal exploration and mining	Good	Good	Good	Good	Low
Cupric Mine	1,000 (2%)	Stone mining; Precious metal exploration and mining	Moderate	Moderate	Moderate	Low	Low
San Francisco	39,000 (93%)	Stone mining at Indian Queen subpopulation; Precious metal exploration and mining at Copper Gulch subpopulation*	Good	Good	Good	Moderate	Moderate

Table 40. Summary of the Frisco clover overall condition scores (Low, Moderate, Good) under the current scenario and four future scenarios. Metrics for evaluating current and future condition are identified in Table 17 and Table 25, respectively. (*There is greater exposure to stone mining and precious metal exploration and mining impacts under the High Level Stone and Precious Metal Mining Scenario).

Population	Estimated Population Size (Percent of Total Population)	Mining Stressors	Overall Current Condition (Resiliency)	Conservation Future Condition (Resiliency)	Low to Moderate Level Precious Metal Exploration and Mining Future Condition (Resiliency)	Moderate Level Stone Mining Future Condition (Resiliency)	High Level Stone and Precious Metal Mining Future Condition (Resiliency)
Blue Mountain	250 (2%)	Stone mining	Moderate	Moderate	Moderate	Low	Low
Grampian Hill	5,000 (32%)	Precious metal exploration and mining	Good	Good	Good	Good	Low
San Francisco	4,300 (27%)	Precious metal exploration and mining*	Good	Good	Good	Good	Good
Lime Mountain	625 (4%)	No mining	Good	Moderate	Moderate	Moderate	Moderate
Tunnel Springs Mountains	2,500 (16%)	No mining	Good	Good	Good	Good	Good
Wah Wah Mountains	3,000 (19%)	No mining	Good	Good	Good	Good	Good

Our evaluation considers impacts from the two mining stressors separately under the Low to Moderate Level Precious Metal Exploration and Mining and Moderate Level Stone Mining Scenarios in order to evaluate and be transparent about the relative contribution of each mining stressor to each species' resiliency, redundancy, and representation. A more realistic moderate future scenario includes the combination of the two mining stressors and the two scenarios. When the two scenarios are combined, the impacts to the three plant species are identical to those described under the Moderate Level Stone Mining Scenario. We have high certainty that stone mining and precious metal exploration activities will continue into the future, and we consider the two low to moderate level scenarios to be reasonable future predictions of plant population condition without voluntary protections.

We are uncertain about the likelihood of future precious metal mining and associated impacts even though we include future mining in the Low to Moderate Level Precious Metal Exploration and Mining and High Level Stone and Precious Metal Mining Scenarios. We consider the moderate mining extent in the Low to Moderate Level Precious Metal Exploration Scenario to be a reasonable scenario for future precious metal mining if known deposits are mined. We consider the High Level Stone and Precious Metal Mining Scenario to be a worst case scenario for future precious metal mining that is only possible if a large source of copper deposit similar in size to Utah's Bingham Canyon deposit in Salt Lake County is located and mined near the Grampian Hill populations of the three species. We will have higher certainty about the likelihood of future precious metal mining within the next year based on the results of current exploration at the deposit areas in the San Francisco mountain range. If the exploration results do not locate mineable deposits, it is unlikely that precious metal mining will impact the Grampian Hill populations of the three species in the near future. However, we would expect precious metal exploration to continue.

While our evaluation does not indicate that future climate conditions alone would have a large effect on the future condition of populations, a drier climate has the potential to reduce the number of suitable habitat microsites available within current population areas. There is also the potential for a range reduction for all three species, particularly in combination with other stressors. Frisco buckwheat and Ostler's peppergrass are likely extremely vulnerable to both occupied and suitable habitat loss and degradation given their small range and small areas of occupied habitat. We expect these two species have the ability to migrate to favorable microsites that are cooler and wetter but only within their existing population areas.

Given the three species' limited ability to migrate and establish outside of their existing ranges, the primary conservation measure should be to preserve the breadth of genetic diversity to support the adaptive capacity (representation) of the three species to develop a tolerance of future climate conditions. Ensuring that plant population areas are in high condition may also help buffer the loss of individuals and minimize an exacerbated effect from vegetative competition for moisture by nonnative invasive species. The same recommendation is applicable to Frisco clover, although the species may have a greater ability to migrate and establish beyond existing population areas. Hence, these considerations are a key part of our conservation measure recommendations for precious metal exploration and mining and stone mining.

Chapter 8. GIS File Summary

GIS Files are available from the Utah Ecological Services Field Office, Salt Lake City, Utah.

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APPENDIX A

FRISCO BUCKWHEAT, OSTLER'S PEPPERGRASS, AND FRISCO CLOVER

CONDITION SCORES

In Chapters 5 and 6, we described the metrics for evaluating current and future condition for the three plant species. The condition category for the current and future condition is based on the average score of the summed factors, see Table 1 and Table 2. Future condition scores are based on the same factors considered for current condition plus the climate resilience factor. For more detail on the climate resilience evaluation, see Appendix B.

Below, we present the condition scores for the current and future scenarios, see Tables 3 - 26. We identify individual scores for each factor, and the average score that determines the condition category. We also identify the population-level exposure to precious metal and gravel mining for each scenario. The evaluation for habitat quality, habitat area, population size, and habitat loss is based on values in the Total Mining Exposure column.

Table 1. Metrics and scoring for Frisco buckwheat, Ostler's peppergrass, and Frisco clover current condition.

Current Condition Metrics						
Condition	Habitat Quality	Habitat Area (Acres)	Population Size	Habitat Loss Category	Average Score Range	Score Spread
Good	(1) Nonnative plant cover 0 - 5%, or (2) Recent disturbance within <5% of habitat area	51 ac or greater in size	> 5,000 individuals	0 - 5% (Low Loss)	2.34 – 3	0.66
Moderate	(1) Nonnative plant cover 0 - 5%, or (2) Recent disturbance within 10% of habitat area	26 - 50 ac in size	500 – 5,000 individuals	5.1 - 10% (Moderate Loss)	1.67 – 2.33	0.67
Low	(1) Nonnative plant cover 6 - 25%, or (2) Recent disturbance within >10% of habitat area	25 ac or less in size	< 500 individuals	>10% (High Loss)	1 – 1.66	0.66

Table 2. Metrics and scoring for Frisco buckwheat, Ostler's peppergrass, and Frisco clover future condition.

Future Condition Metrics							
Condition	Habitat Quality	Habitat Area (Acres)	Population Size	Habitat Loss Category	Climate Change Resilience	Average Score Range	Score Spread
Good	(1) Nonnative plant cover 0 - 5%, or (2) Recent disturbance within <5% of habitat area	51 ac or greater in size	> 5,000 individuals	0 - 5% (Low Loss)	Low radiation load, and multiple aspects	2.34 – 3	0.66
Moderate	(1) Nonnative plant cover 0 - 5%, or (2) Recent disturbance within 10% of habitat area	26 - 50 ac in size	500 – 5,000 individuals	5.1 - 10% (Moderate Loss)	(1) Low radiation load, and one aspect; or (2) Moderate or high radiation load, and multiple aspects	1.67 – 2.33	0.67
Low	(1) Nonnative plant cover 6 - 25%, or (2) Recent disturbance within >10% of habitat area	25 ac or less in size	< 500 individuals	>10% (High Loss)	Moderate or high radiation load, and one aspect	1 – 1.66	0.66

SCORES FOR CURRENT CONDITION

Table 3. Frisco buckwheat Current Condition Scores.

Population	Habitat Quality	Habitat Area	Population Size	Habitat Loss	Habitat Loss	Sum	Average	Condition Category
Grampian Hill	3	3	3	3	3	15	3	Good
Cupric Mine	3	2	2	1	1	9	1.8	Moderate
San Francisco	3	3	3	2	2	13	2.6	Good

Table 4. Frisco buckwheat Current Scenario: Precious Metal and Gravel Mining Exposure. The evaluation for habitat quality, habitat area, population size, and habitat loss is based on values in the Total Mining Exposure column.

Population	Original Acreage (ac)	Precious Metal Mining Exposure (ac)	Remaining Acreage (ac)	Gravel Mining Exposure (ac)	Total Remaining Acreage (ac)	Total Mining Exposure (%)
Grampian Hill	188	0	188	0	188	0%
Cupric Mine	45	0	45	4.3	40.7	10%
San Francisco	63.5	0	63.5	3.5	60	6%

Table 5. Ostler's peppergrass Current Condition Scores.

Population	Habitat Quality	Habitat Area	Population Size	Habitat Loss	Habitat Loss	Sum	Average	Condition Category
Grampian Hill	3	3	2	3	3	14	2.8	Good
Cupric Mine	3	2	2	1	1	9	1.8	Moderate
San Francisco	3	2	3	3	3`	14	2.8	Good

Table 6. Ostler's peppergrass Current Scenario: Precious Metal and Gravel Mining Exposure. The evaluation for habitat quality, habitat area, population size, and habitat loss is based on values in the Total Mining Exposure column.

Population	Original Acreage (ac)	Precious Metal Mining Exposure (ac)	Remaining Acreage (ac)	Gravel Mining Exposure (ac)	Total Remaining Acreage (ac)	Total Mining Exposure (%)
Grampian Hill	84	0	84	0	84	0%
Cupric Mine	29.5	0	29.5	4.3	25.2	15%
San Francisco	39.5	0	39.5	0	39.5	0%

Table 7. Frisco clover Current Condition Scores.

Population	Habitat Quality	Habitat Area	Population Size	Habitat Loss	Habitat Loss	Sum	Average	Condition Category
Blue Mountain	3	1	1	3	3	11	2.2	Moderate
Grampian Hill	3	2	3	3	3	14	2.8	Good
San Francisco	3	2	2	3	3	13	2.6	Good
Lime Mountain	3	1	2	3	3	12	2.4	Good
Tunnel Springs Mountain	3	3	2	3	3	14	2.8	Good
Wah Wah Mountain	3	3	2	3	3	14	2.8	Good

Table 8. Frisco clover Current Scenario: Precious Metal and Gravel Mining Exposure. The evaluation for habitat quality, habitat area, population size, and habitat loss is based on values in the Total Mining Exposure column.

Population	Original Acreage (ac)	Precious Metal Mining Exposure (ac)	Remaining Acreage (ac)	Gravel Mining Exposure (ac)	Total Remaining Acreage (ac)	Total Mining Exposure (ac)
Blue Mountain	8	0	8	0	0	0%
Grampian Hill	97	0	97	0	97	0%
San Francisco	46	0	46	0	46	0%
Lime Mountain	14.5	0	14.5	0	14.5	0%
Tunnel Springs Mountain	111	0	111	0	111	0%
Wah Wah Mountain	83.5	0	83.5	0	83.5	0%

FUTURE CONDITION SCENARIO 1: CONSERVATION

Table 9. Frisco buckwheat Scenario 1: Conservation Future Condition Scores.

Population	Habitat Quality	Habitat Area	Population Size	Habitat Loss	Habitat Loss	Climate Change Resilience	Sum	Average	Condition Category
Grampian Hill	3	3	3	3	3	2	17	3	Good
Cupric Mine	3	2	2	1	1	2	11	1.83	Moderate
San Francisco	3	3	3	2	2	2	15	2.5	Good

Table 10. Frisco buckwheat Future Scenario 1: Conservation Precious Metal and Gravel Mining Exposure. The evaluation for habitat quality, habitat area, population size, and habitat loss is based on values in the Total Mining Exposure column.

Population	Original Acreage (ac)	Precious Metal Mining Exposure (ac)	Remaining Acreage (ac)	Gravel Mining Exposure (ac)	Total Remaining Acreage (ac)	Total Mining Exposure (%)
Grampian Hill	188	0	188	0	188	0%
Cupric Mine	45	0	45	4.3	40.7	10%
San Francisco	63.5	0	63.5	3.5	60	6%

Table 11. Ostler's peppergrass Scenario 1: Conservation Future Condition Scores.

Population	Habitat Quality	Habitat Area	Population Size	Habitat Loss	Habitat Loss	Climate Change Resilience	Sum	Average	Condition Category
Grampian Hill	3	3	2	3	3	3	17	2.83	Good
Cupric Mine	3	2	2	1	1	2	11	1.83	Moderate
San Francisco	3	2	3	3	3	2	16	2.67	Good

Table 12. Ostler's peppergrass Future Scenario 1: Conservation Precious Metal and Gravel Mining Exposure. The evaluation for habitat quality, habitat area, population size, and habitat loss is based on values in the Total Mining Exposure column.

Population	Original Acreage (ac)	Precious Metal Mining Exposure (ac)	Remaining Acreage (ac)	Gravel Mining Exposure (ac)	Total Remaining Acreage (ac)	Total Mining Exposure (%)
Grampian Hill	84	0	84	0	84	0%
Cupric Mine	29.5	0	29.5	4.3	25.2	15%
San Francisco	39.5	0	39.5	0	39.5	0%

Table 13. Frisco clover Scenario 1: Conservation Future Condition Scores.

Population	Habitat Quality	Habitat Area	Population Size	Habitat Loss	Habitat Loss	Climate Change Resilience	Sum	Average	Condition Category
Blue Mountain	3	1	1	3	3	1	12	2	Moderate
Grampian Hill	3	2	3	3	3	3	17	2.83	Good
San Francisco	3	2	2	3	3	2	15	2.5	Good
Lime Mountain	3	1	2	3	3	2	14	2.33	Moderate
Tunnel Springs Mountain	3	3	2	3	3	2	16	2.67	Good
Wah Wah Mountain	3	3	2	3	3	2	16	2.67	Good

Table 14. Frisco clover Future Scenario 1: Conservation Precious Metal and Gravel Mining Exposure. The evaluation for habitat quality, habitat area, population size, and habitat loss is based on values in the Total Mining Exposure column.

Population	Original Acreage (ac)	Precious Metal Mining Exposure (ac)	Remaining Acreage (ac)	Gravel Mining Exposure (ac)	Total Remaining Acreage (ac)	Total Mining Exposure (ac)
Blue Mountain	8	0	8	0	0	0%
Grampian Hill	97	0	97	0	97	0%
San Francisco	46	0	46	0	46	0%
Lime Mountain	14.5	0	14.5	0	14.5	0%
Tunnel Springs Mountain	111	0	111	0	111	0%
Wah Wah Mountain	83.5	0	83.5	0	83.5	0%

FUTURE CONDITION SCORES: LOW TO MODERATE LEVEL PRECIOUS METAL EXPLORATION AND MINING SCENARIO

Table 15. Frisco buckwheat Future Scenario 2: Low to Moderate Level Precious Metal Exploration and Mining Scores.

Population	Habitat Quality	Habitat Area	Population Size	Habitat Loss	Habitat Loss	Climate Change Resilience	Sum	Average	Condition Category
Grampian Hill	2	3	3	3	3	2	16	2.67	Good
Cupric Mine	3	2	2	1	1	2	11	1.83	Moderate
San Francisco	3	3	3	2	2	2	15	2.5	Good

Table 16. Frisco buckwheat Future Scenario 2: Low to Moderate Level Precious Metal Exploration and Mining Exposure. The evaluation for habitat quality, habitat area, population size, and habitat loss is based on values in the Total Mining Exposure column.

Population	Original Acreage (ac)	Precious Metal Mining Exposure (ac)	Remaining Acreage (ac)	Gravel Mining Exposure (ac)	Total Remaining Acreage (ac)	Total Mining Exposure (%)
Grampian Hill	188	7.5	180.5	0	180.5	4%
Cupric Mine	45	0	45	0	45	0%
San Francisco	63.5	0	63.5	0	63.5	0%

Table 17. Ostler's peppergrass Future Scenario 2: Low to Moderate Level Precious Metal Exploration and Mining Scores.

Population	Habitat Quality	Habitat Area	Population Size	Habitat Loss	Habitat Loss	Climate Change Resilience	Sum	Average	Condition Category
Grampian Hill	2	3	2	3	3	3	16	2.67	Good
Cupric Mine	3	2	2	1	1	2	11	1.83	Moderate
San Francisco	3	2	3	3	3	2	16	2.67	Good

Table 18. Ostler's peppergrass Future Scenario 2: Low to Moderate Level Precious Metal Exploration and Mining Exposure. The evaluation for habitat quality, habitat area, population size, and habitat loss is based on values in the Total Mining Exposure column.

Population	Original Acreage (ac)	Precious Metal Mining Exposure (ac)	Remaining Acreage (ac)	Gravel Mining Exposure (ac)	Total Remaining Acreage (ac)	Total Mining Exposure (%)
Grampian Hill	84	4	80	0	80	4.8%
Cupric Mine	29.5	0	29.5	0	29.5	0%
San Francisco	39.5	0	39.5	0	39.5	0%

Table 19. Frisco clover Future Scenario 2: Low to Moderate Level Precious Metal Exploration and Mining Scores.

Population	Habitat Quality	Habitat Area	Population Size	Habitat Loss	Habitat Loss	Climate Change Resilience	Sum	Average	Condition Category
Blue Mountain	3	1	1	3	3	1	12	2	Moderate
Grampian Hill	2	2	3	3	3	3	16	2.67	Good
San Francisco	3	2	2	3	3	2	15	2.5	Good
Lime Mountain	3	1	2	3	3	2	14	2.33	Moderate
Tunnel Springs Mountain	3	3	2	3	3	2	16	2.67	Good
Wah Wah Mountain	3	3	2	3	3	2	16	2.67	Good

Table 20. Frisco clover Future Scenario 2: Low to Moderate Level Precious Metal Exploration and Mining Exposure. The evaluation for habitat quality, habitat area, population size, and habitat loss is based on values in the Total Mining Exposure column.

Population	Original Acreage (ac)	Precious Metal Mining Exposure (ac)	Remaining Acreage (ac)	Gravel Mining Exposure (ac)	Total Remaining Acreage (ac)	Total Mining Exposure (ac)
Blue Mountain	8	0	8	0	0	0%
Grampian Hill	97	4.5	92.5	0	92.5	4.6%
San Francisco	46	0	46	0	46	0%
Lime Mountain	14.5	0	14.5	0	14.5	0%
Tunnel Springs Mountain	111	0	111	0	111	0%
Wah Wah Mountain	83.5	0	83.5	0	83.5	0%

FUTURE CONDITION SCORES: MODERATE LEVEL STONE MINING SCENARIO

Table 21. Frisco buckwheat Future Scenario 3: Moderate Level Stone Mining Condition Scores.

Population	Habitat Quality	Habitat Area	Population Size	Habitat Loss	Habitat Loss	Climate Change Resilience	Sum	Average	Condition Category
Grampian Hill	3	3	3	3	3	2	17	2.83	Good
Cupric Mine	3	1	1	1	1	2	9	1.5	Low
San Francisco	3	2	3	1	1	2	12	2	Moderate

Table 22. Frisco buckwheat Future Scenario 3: Moderate Level Stone Mining. The evaluation for habitat quality, habitat area, population size, and habitat loss is based on values in the Total Mining Exposure column. (*Note, this is the minimum amount of habitat loss needed to achieve the Low habitat area condition rank).

Population	Original Acreage (ac)	Precious Metal Mining Exposure (ac)	Remaining Acreage (ac)	Gravel Mining Exposure (ac)	Total Remaining Acreage (ac)	Total Mining Exposure (%)
Grampian Hill	188	0	188	0	188	0%
Cupric Mine	45	0	45	21*	24	53%
San Francisco	63.5	0	63.5	13.5*	50	21%

Table 23. Ostler's peppergrass Future Scenario 3: Moderate Level Stone Mining Condition Scores.

Population	Habitat Quality	Habitat Area	Population Size	Habitat Loss	Habitat Loss	Climate Change Resilience	Sum	Average	Condition Category
Grampian Hill	3	3	2	3	3	3	17	2.83	Good
Cupric Mine	3	1	1	1	1	2	9	1.5	Low
San Francisco	3	2	3	1	1	2	12	2	Moderate

Table 24. Ostler's peppergrass Future Scenario 3: Moderate Level Stone Mining Exposure. The evaluation for habitat quality, habitat area, population size, and habitat loss is based on values in the Total Mining Exposure column. (*Note, this is the minimum amount of habitat loss needed to achieve the Low habitat area condition rank).

Population	Original Acreage (ac)	Precious Metal Mining Exposure (ac)	Remaining Acreage (ac)	Gravel Mining Exposure (ac)	Total Remaining Acreage (ac)	Total Mining Exposure (%)
Grampian Hill	84	0	84	0	84	0%
Cupric Mine	29.5	0	29.5	4.6*	24.9	16%
San Francisco	39.5	0	39.5	4.5*	30	11%

Table 25. Frisco clover Future Scenario 3: Moderate Level Stone Mining Condition Scores.

Population	Habitat Quality	Habitat Area	Population Size	Habitat Loss	Habitat Loss	Climate Change Resilience	Sum	Average	Condition Category
Blue Mountain	3	1	1	1	1	1	8	1.33	Low
Grampian Hill	3	2	3	3	3	3	17	2.8	Good
San Francisco	3	2	2	3	3	2	15	2.5	Good
Lime Mountain	3	1	2	3	3	2	14	2.33	Moderate
Tunnel Springs Mountain	3	3	2	3	3	2	16	2.67	Good
Wah Wah Mountain	3	3	2	3	3	2	16	2.67	Good

Table 26. Frisco clover Future Scenario 3: Moderate Level Stone Mining Exposure. The evaluation for habitat quality, habitat area, population size, and habitat loss is based on values in the Total Mining Exposure column. (*Note, this is the minimum amount of habitat loss needed to achieve the Low habitat area condition rank).

Population	Original Acreage (ac)	Precious Metal Mining Exposure (ac)	Remaining Acreage (ac)	Gravel Mining Exposure (ac)	Total Remaining Acreage (ac)	Total Mining Exposure (ac)
Blue Mountain	8	0	8	.81	7.17*	10.1%
Grampian Hill	97	0	97	0	97	0%
San Francisco	46	0	46	0	46	0%
Lime Mountain	14.5	0	14.5	0	14.5	0%
Tunnel Springs Mountain	111	0	111	0	111	0%
Wah Wah Mountain	83.5	0	83.5	0	83.5	0%

FUTURE CONDITION SCORES: HIGH LEVEL STONE AND PRECIOUS METAL MINING SCENARIO

Table 27. Frisco buckwheat Future Scenario 4: High Level Stone and Precious Metal Mining Scores.

Population	Habitat Quality	Habitat Area	Population Size	Habitat Loss	Habitat Loss	Climate Change Resilience	Sum	Average	Condition Category
Grampian Hill	1	1	Unknown	1	1	2	6	1.2	
Cupric Mine	1	1	Low	1	1	2	6	1.2	
San Francisco	1	2	3	1	1	2	10	1.67	

Table 28. Frisco buckwheat Future Scenario 4: High level Stone and Precious Metal Mining Exposure. The evaluation for habitat quality, habitat area, population size, and habitat loss is based on values in the Total Mining Exposure column.

Population	Original Acreage (ac)	Precious Metal Mining Exposure (ac)	Remaining Acreage (ac)	Gravel Mining Exposure (ac)	Total Remaining Acreage (ac)	Total Mining Exposure (%)
Grampian Hill	188	168	20	0	20	89%
Cupric Mine	45	20	25	45	0	100%
San Francisco	63.5	6	57.5	27.5	30	53%

Table 29. Ostler's peppergrass Future Scenario 4: High Level Stone and Precious Metal Mining Scores.

Population	Habitat Quality	Habitat Area	Population Size	Habitat Loss	Habitat Loss	Climate Change Resilience	Sum	Average	Condition Category
Grampian Hill	1	1	Unknown	1	1	3	7	1.4	Low
Cupric Mine	1	1	Low	1	1	2	6	1.2	Low
San Francisco	1	2	3	1	1	2	10	1.67	Moderate

Table 30. Ostler's peppergrass Future Scenario 4: High Level Stone and Precious Metal Mining Precious Metal and Gravel Mining Exposure. The evaluation for habitat quality, habitat area, population size, and habitat loss is based on values in the Total Mining Exposure column.

Population	Original Acreage (ac)	Precious Metal Mining Exposure (ac)	Remaining Acreage (ac)	Gravel Mining Exposure (ac)	Total Remaining Acreage (ac)	Total Mining Exposure (%)
Grampian Hill	84	83	1	0	1	99%
Cupric Mine	29.5	15.5	14	29.5	0	100%
San Francisco	39.5	4.5	35	9	26	34%

Table 31. Frisco clover Future Scenario 4: High Level Stone and Precious Metal Mining Condition Scores.

Population	Habitat Quality	Habitat Area	Population Size	Habitat Loss	Habitat Loss	Climate Change Resilience	Sum	Average	Condition Category
Blue Mountain	1	1	1	1	1	1	6	1	Low
Grampian Hill	1	1	Unknown	1	1	3	7	1.4	Low
San Francisco	3	2	2	3	3	2	15	2.5	Good
Lime Mountain	3	1	2	3	3	2	14	2.33	Moderate
Tunnel Springs Mountain	3	3	2	3	3	2	16	2.67	Good
Wah Wah Mountain	3	3	2	3	3	2	16	2.67	Good

Table 32. Frisco clover Future Scenario 4: High Level Stone and Precious Metal Mining Exposure. The evaluation for habitat quality, habitat area, population size, and habitat loss is based on values in the Total Mining Exposure column.

Population	Original Acreage (ac)	Precious Metal Mining Exposure (ac)	Remaining Acreage (ac)	Gravel Mining Exposure (ac)	Total Remaining Acreage (ac)	Total Mining Exposure (ac)
Blue Mountain	8	0	8	8	0	100%
Grampian Hill	97	93	4	0	4	96%
San Francisco	46	0	46	0	46	0%
Lime Mountain	14.5	0	14.5	0	14.5	0%
Tunnel Springs Mountain	111	0	111	0	111	0%
Wah Wah Mountain	83.5	0	83.5	0	83.5	0%

APPENDIX B

FRISCO BUCKWHEAT, OSTLER'S PEPPERGRASS, AND FRISCO CLOVER CLIMATE RESILIENCE EVALUATION

In Chapter 6, we described the methodology and the metrics for evaluating climate change resilience for the three plant species. The climate change resilience category for each species' future condition is based on the relative radiation load factor and the presence or absence of multiple aspects within occupied habitat, see Table 1. We incorporated the climate resilience scores into our evaluation of future condition. Population scores of the climate resilience evaluation are identified in Appendix A.

Here we discuss the methodology for calculating the relative solar radiation load for the plant populations and present the results. We calculated the amount of annual global solar radiation (ASolGlobYr) for all populations (i.e., occupied habitat) of the three plant species. The annual global solar radiation is the total amount of radiation calculated for a particular area in a year. First, we used solar insolation maps to calculate annual total global radiation load across 30 m^2 resolution grid cells. We summed the radiation load across each grid cell that overlapped within plant populations. We then divided the summed population radiation load by the total area of occupied habitat to normalize the values by the size of each population. The normalized values allow the populations to be compared with each other. Radiation load values are presented in Watt Hours (WH) per square meter (m^2). The total Watt Hours for each population divided by the area of each population is the same as the mean Watt Hours for each population because each grid cell is the same size. Next, we took the spread of scores for all three plant species and divided them into three intervals for our low, moderate, and good ranking (Table 2; Table 3). (Note: The geodatabase files and arcgis model builder python scripts used to calculate the relative Annual Global Solar Radiation are titled: Final_AllPolysSolarAnalysis.gdb and Toolbox_PopSolarCalcs.tbx, and are stored in the following folder location: J:Lewinsohn/GIS/Frisco_Endemics_SSA).

Table 1. Metrics for evaluating climate resilience.

Future Climate Resilience Categories		
Resilience	**Relative Radiation Load**	**Multiple Aspects (Y/N)**
Good	Low	Yes
Moderate	Low	No
	Moderate	Yes
	High	Yes
Low	Moderate	No
	High	No

Table 2. Plant population annual global solar radiation values and relative radiation load categories.

Species	Population	Annual Global Solar Radiation (ASolGlobYr) (MW/m^2)	Relative Radiation Load Category
Frisco buckwheat	Grampian Hill	1,450,254	Medium
	Cupric Mine	1,475,957	Medium
	San Francisco	1,580,623	High
Ostler's peppergrass	Grampian Hill	1,365,438	Low
	Cupric Mine	1,465,088	Medium
	San Francisco	1,599,560	High
Frisco clover	Blue Mountain	1,503,341	Medium
	Grampian Hill	1,369,603	Low
	San Francisco	1,490,774	Medium
	Lime Mountain	1,467,239	Medium
	Tunnel Springs BLM	1,497,596	Medium
	Tunnel Springs USFS	1,470,739	Medium
	Wah Wah Mountains	1,502,291	Medium

Table 3. Relative radiation load values for each category.

Relative Radiation Load Category	Annual Global Solar Radiation (ASolGlobYr) (MW/m^2)
Low	1,365,439 to 1,443,480
Medium	1,443,481 to 1,521,521
High	1,521,522 to 1,599,561
Spread = 78,041	

APPENDIX C

FRISCO BUCKWHEAT, OSTLER'S PEPPERGRASS, AND FRISCO CLOVER POPULATION AREA DELINEATION

In Chapter 1, we defined plant population areas for all three species. In Chapter 4, we included a recommended conservation measure for surface disturbance caps within plant population areas where precious metal mining or gravel mining occur. Here we summarize our methodology for defining plant population areas, and present plant population area acreages (Table 1) and extent (Figures 1 - 7) only for those populations where one or both mining stressors occur.

We utilized the draft suitable habitat models developed by Lara Juliusson, Service Region 6 Office of Decision Support, to identify suitable habitat for all three plant species (Appendix E). For our evaluation, we incorporated all areas of high habitat suitability as identified by 3, 4, or 5 habitat models, otherwise known as areas where model concordance was either 3, 4, or 5. We utilized the draft Frisco buckwheat habitat model to identify suitable habitat for Frisco buckwheat and Ostler's peppergrass due to the model limitations of the Ostler's peppergrass habitat model. The draft Ostler's peppergrass suitable habitat model over-predicts the amount of suitable habitat for the species because of the low number of occupancy points for the species. We utilized the draft Frisco clover habitat model to identify suitable habitat for Frisco clover.

We delineated the boundaries of population areas to include occupied and suitable habitat within 2 kilometers (1.24 miles) of occupied habitat for populations with a mining stressor. This distance is based on the standardized methods used by the national network of Natural Heritage Programs to identify the species' element occurrences (EOs). EOs are plant points that are grouped together based on geographic proximity within a 2 km (1.24 miles) distance separated by suitable habitat (NatureServe 2004, p. 6). Our populations differ slightly from this protocol in a few instances where the distance slightly exceeded 2 km (1.24 miles). We expect all three species have the ability to disperse and colonize within this area delineation (section 6.1). We amended the boundary in certain instances to include suitable habitat on Bureau of Land Management (BLM lands) within the range of the species. Population area acreages are identified in Table 1. These acreages should be amended following any updates to the suitable habitat models.

Table 1. Population area acreages for Frisco buckwheat, Ostler's peppergrass, and Frisco clover. Population areas were calculated for plant populations with a mining stressor.

Species	Population	Population Area Acreage				Disturbance Acreage with 2.5% cap
		3 Model Concordance	4 Model Concordance	5 Model Concordance	Total	
Frisco buckwheat and Ostler's peppergrass	Grampian Hill	184	142	127	453	11
	Cupric Mine	346	323	335	1004	25
	San Francisco	399	386	274	1059	26
	Totals	**928**	**851**	**737**	**2517**	**63**
Frisco clover	Blue Mountain	81	75	60	216	5
	Grampian Hill	150	354	965	1469	37
	San Francisco	282	285	424	991	25
	Totals	**513**	**714**	**1449**	**2676**	**67**

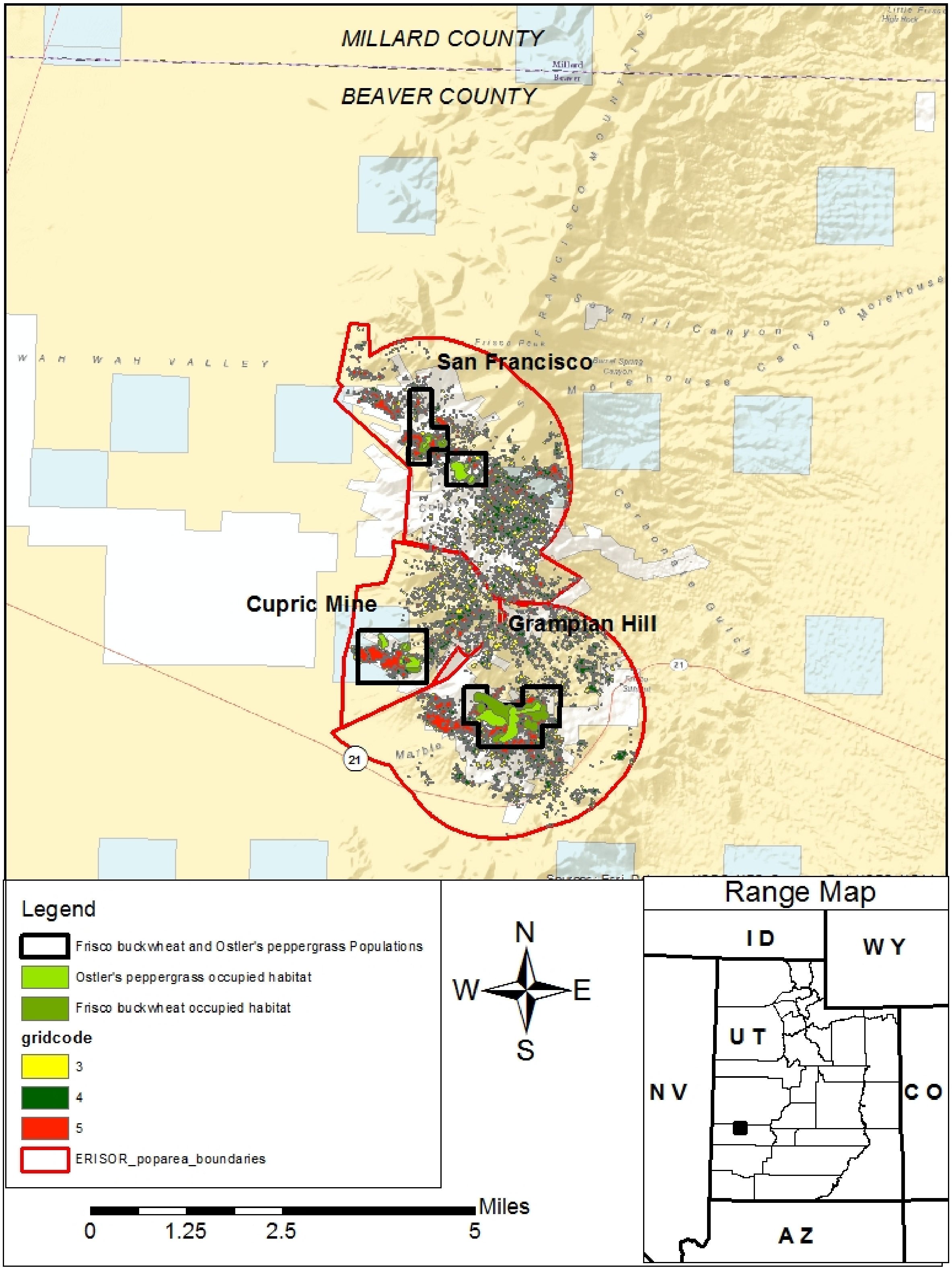

Figure 1. Frisco buckwheat and Ostler's peppergrass three Population Areas. Gridcode value indicates the concordance of models for a particular area.

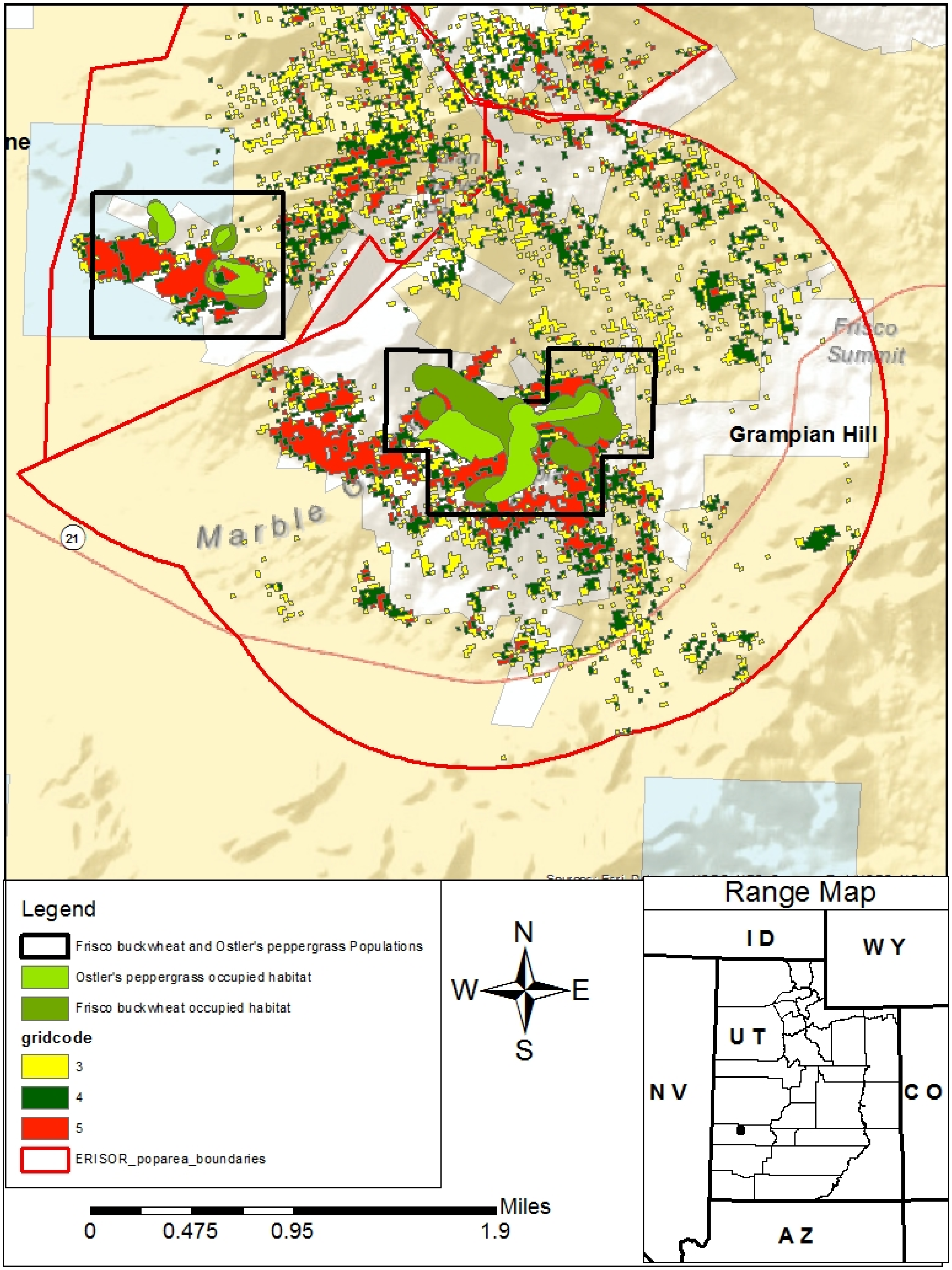

Figure 2. Frisco buckwheat and Ostler's peppergrass Grampian Hill Population Area. Gridcode value indicates the concordance of models for a particular area.

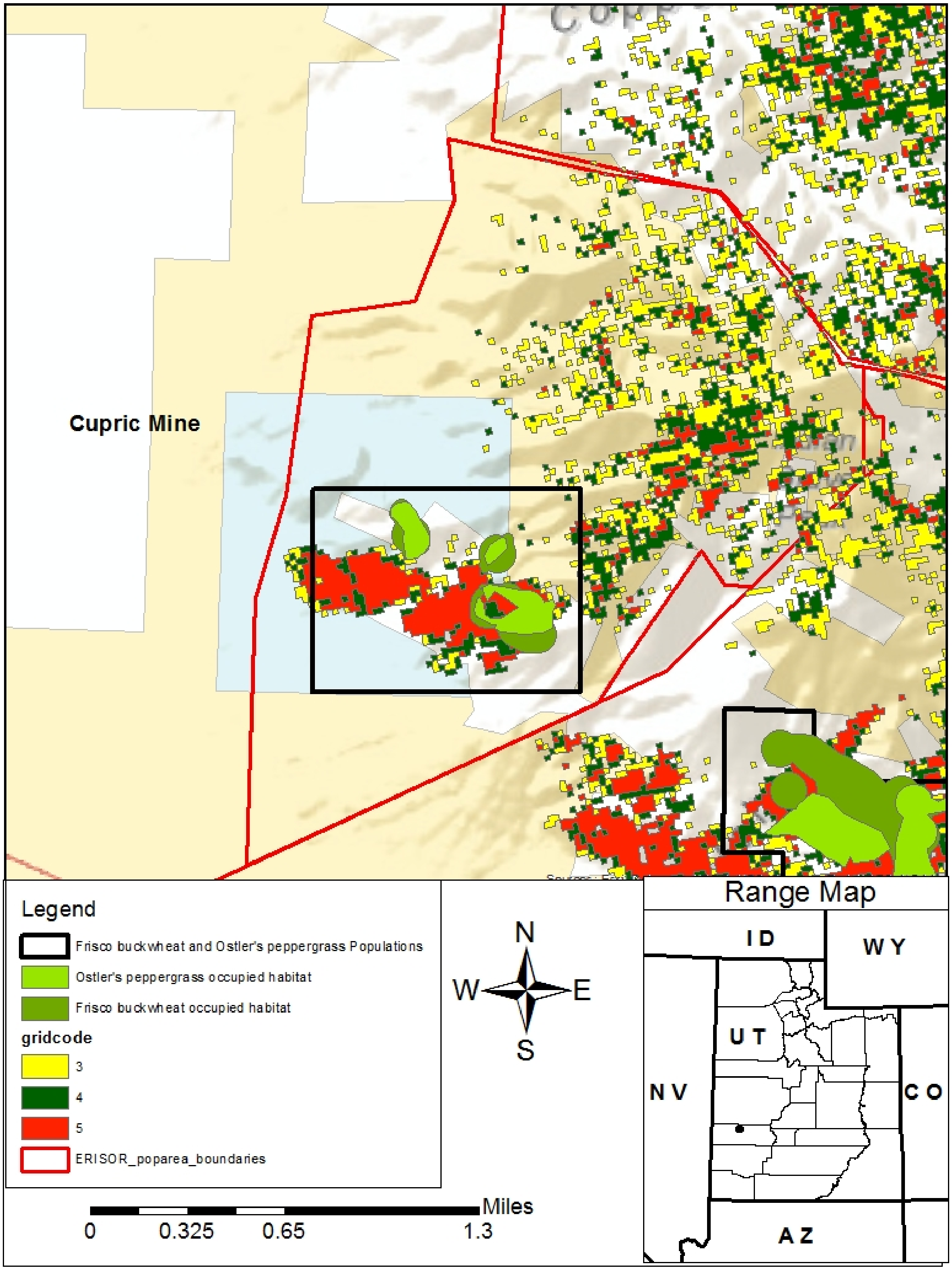

Figure 3. Frisco buckwheat and Ostler's peppergrass Cupric Mine Population Area. Gridcode value indicates the concordance of models for a particular area.

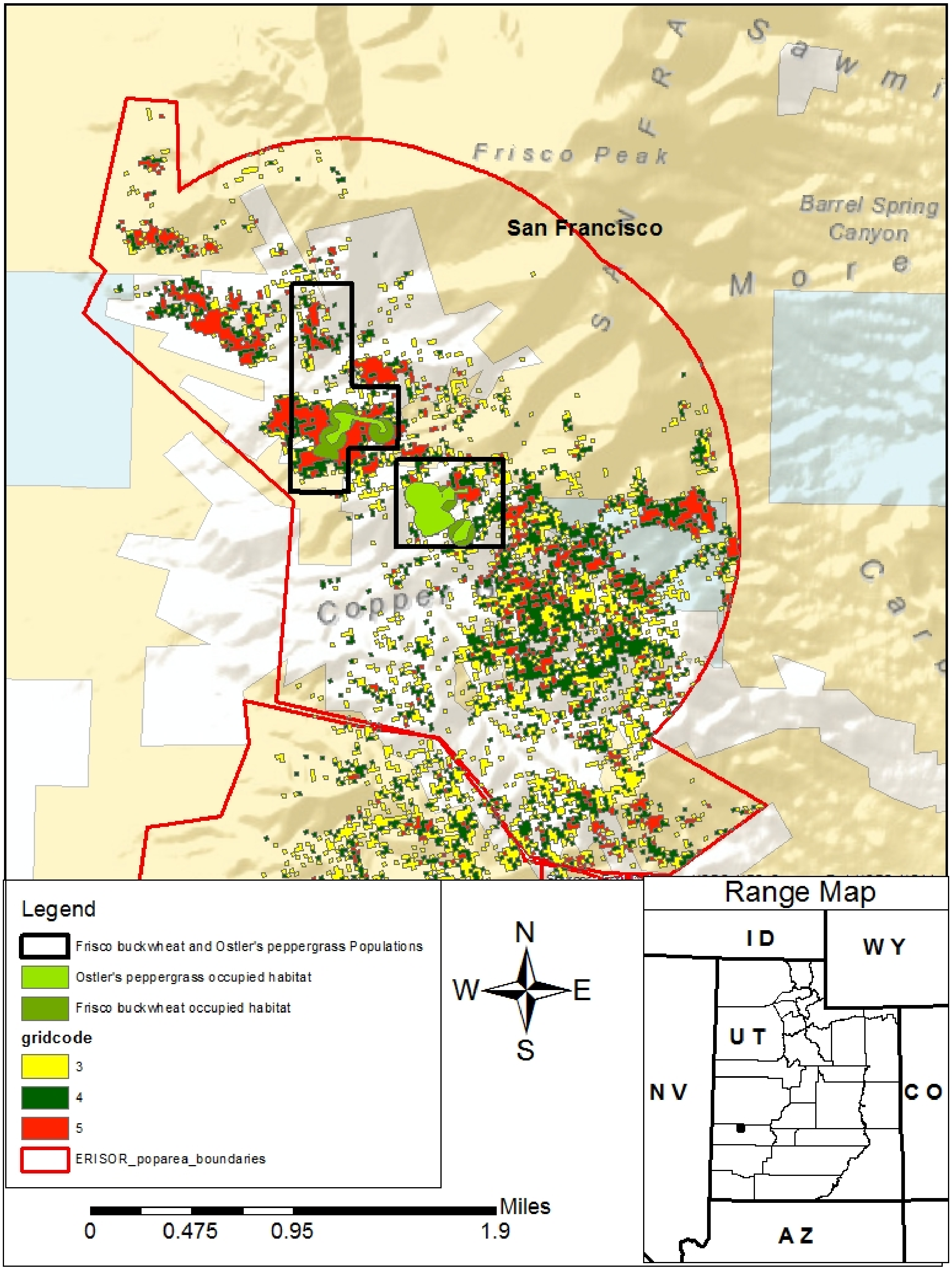

Figure 4. Frisco buckwheat and Ostler's peppergrass San Francisco Population Area. Gridcode value indicates the concordance of models for a particular area.

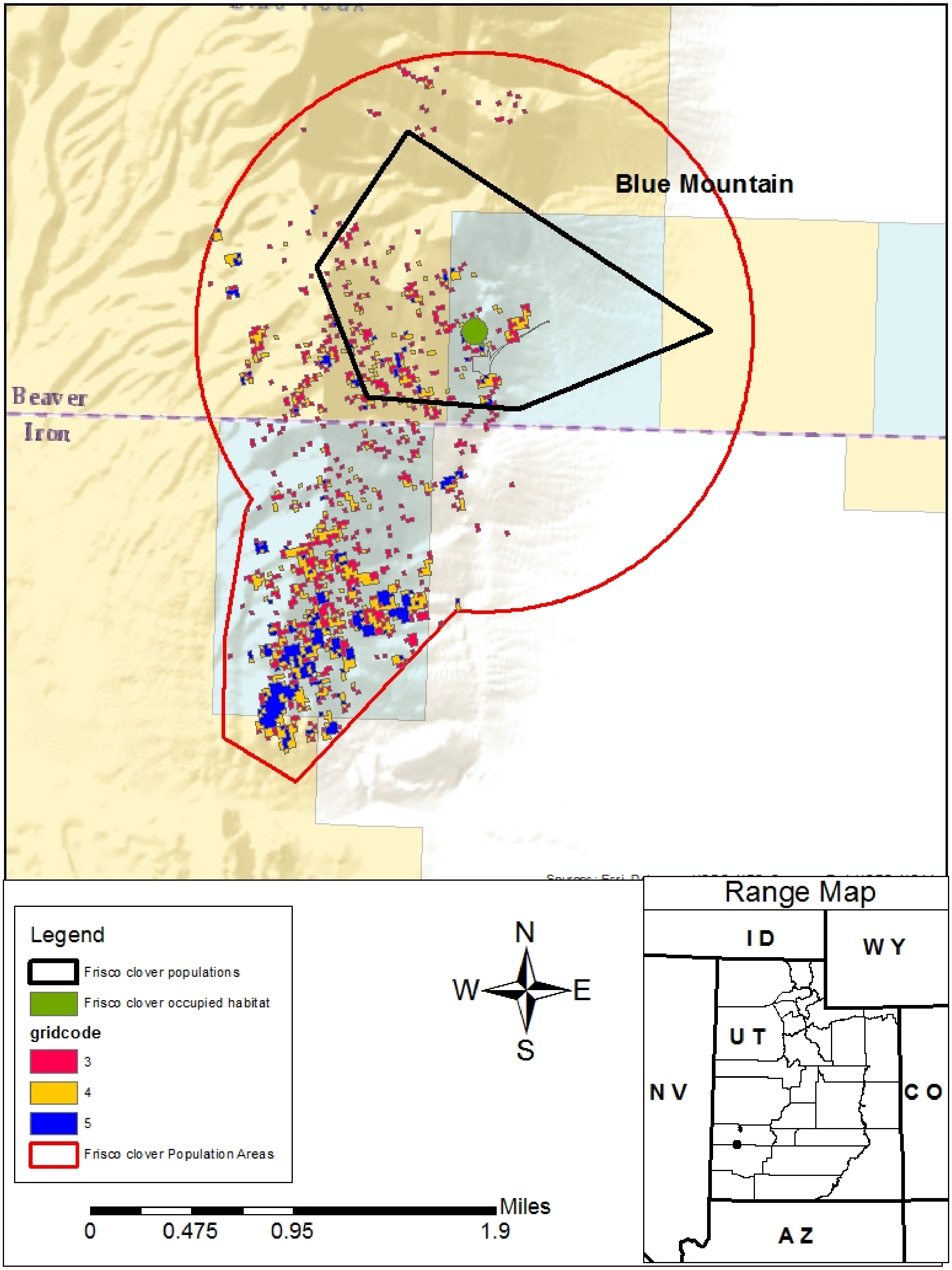

Figure 5. Frisco clover Blue Mountain Population Area. Gridcode value indicates the concordance of models for a particular area.

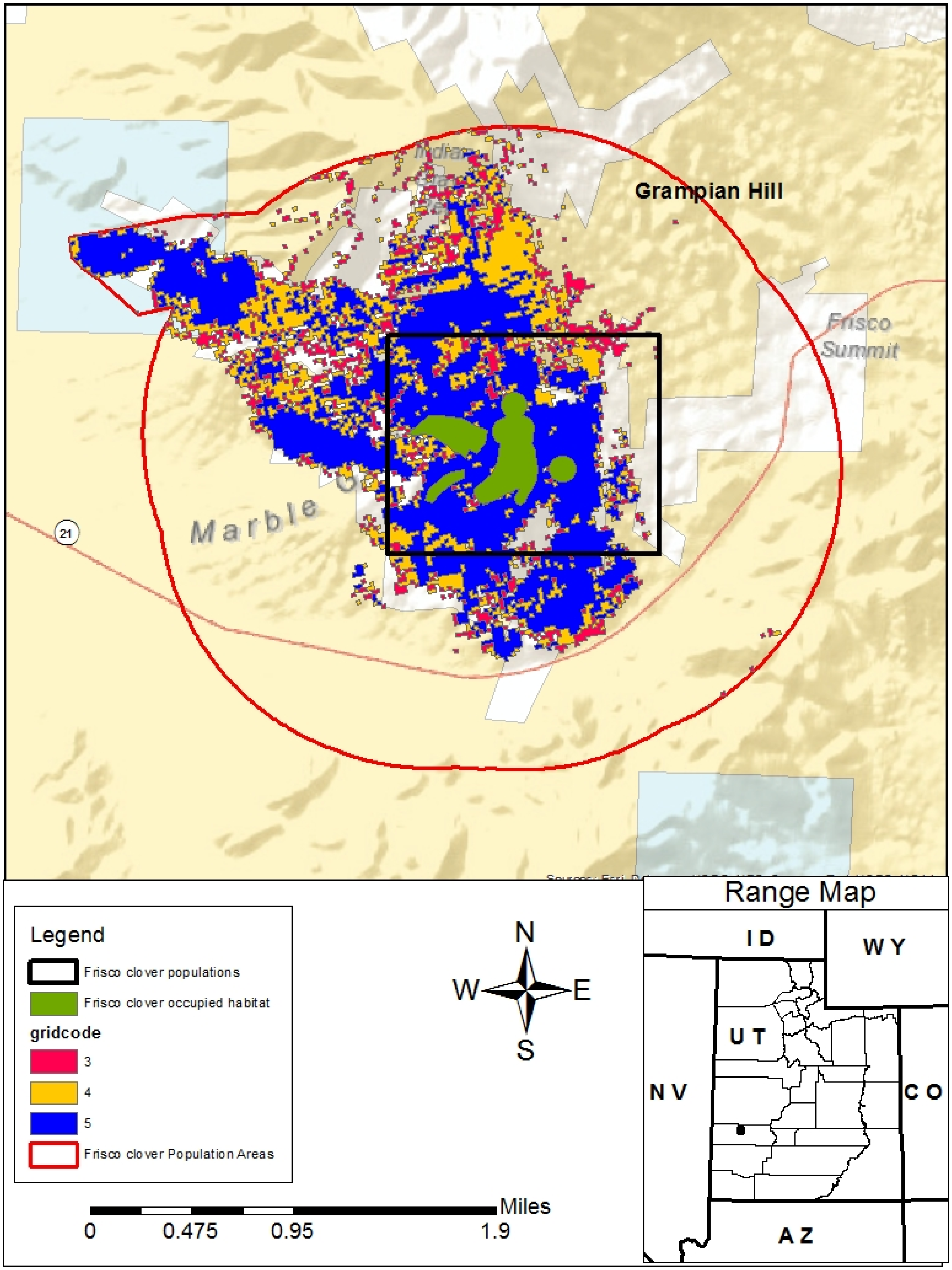

Figure 6. Frisco clover Grampian Hill Population Area. Gridcode value indicates the concordance of models for a particular area.

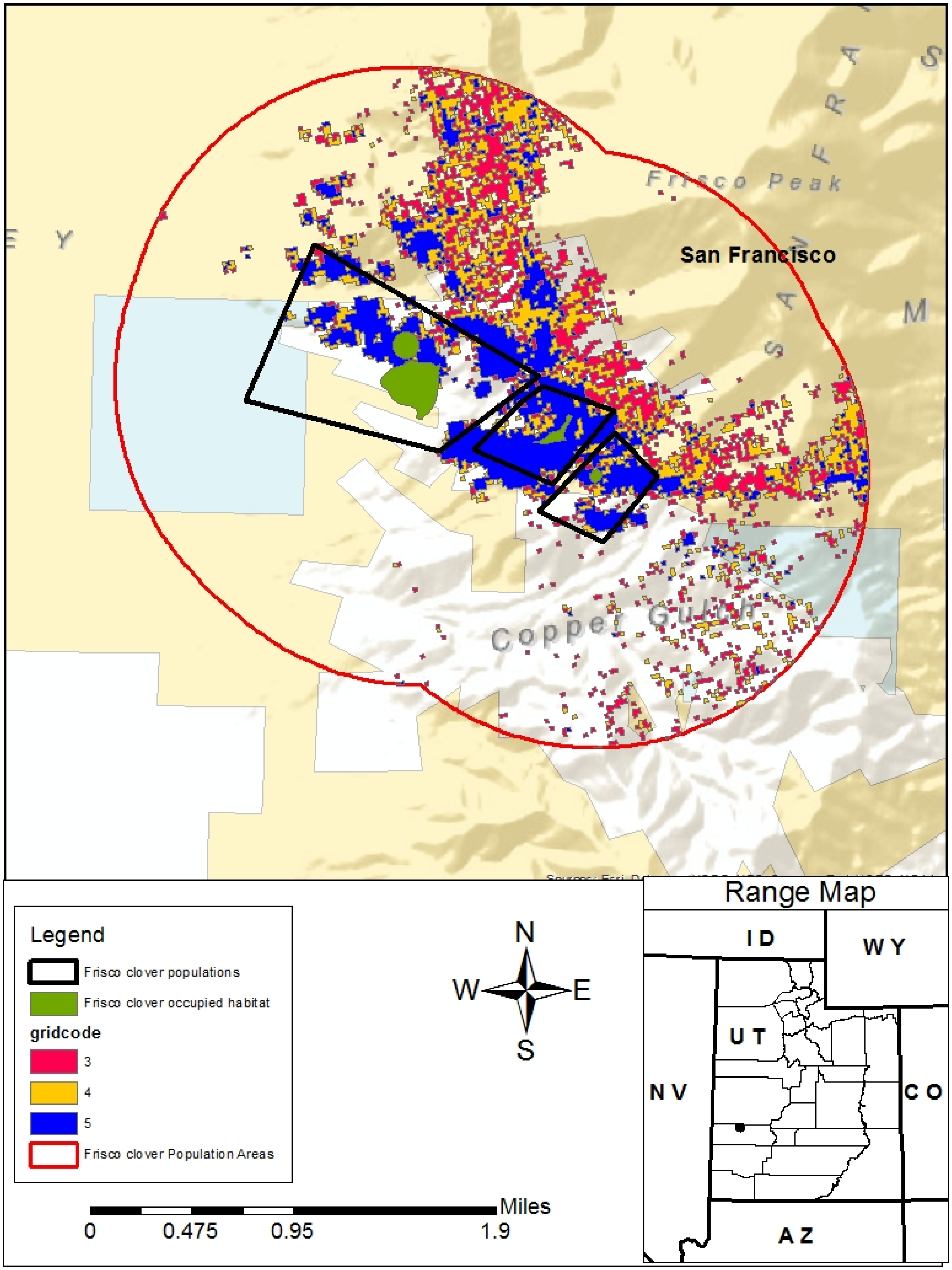

Figure 7. Frisco clover San Francisco Population Area. Gridcode value indicates the concordance of models for a particular area.

APPENDIX D

FRISCO BUCKWHEAT, OSTLER'S PEPPERGRASS, AND FRISCO CLOVER

ACTIVE GRAVEL QUARRY EVALUATION

In Chapters 3 and 4, we discussed the three active gravel quarries within the range of the three plant species: the Southern White/Mountain Rose, Indian Queen, and Courgraph mines. Here we summarize the information we have about the three active gravel quarries (Table 1). We depict the location of each stone mine and the current permit area relative to plant populations in Figures 1, 2, and 3.

Table 1. Active gravel quarries where Frisco buckwheat, Ostler's peppergrass, and Frisco clover occur.

Gravel Mine	Land-ownership	Original Permit Year	Current Permit Type	Permitted Area	Reclamation Status	Mine Status
Southern White/ Mountain Rose	Private	1999	State small mine permit	7 ac (2.8 ha)	None	Active
Indian Queen	Private/BLM	1993	State large mine permit	10 ac (4.0 ha)	Partially reclaimed 6 ac (2.4 ha)	Active
Courgraph	State	1993	State small mine permit	9.9 ac (4.0 ha)	None	Active

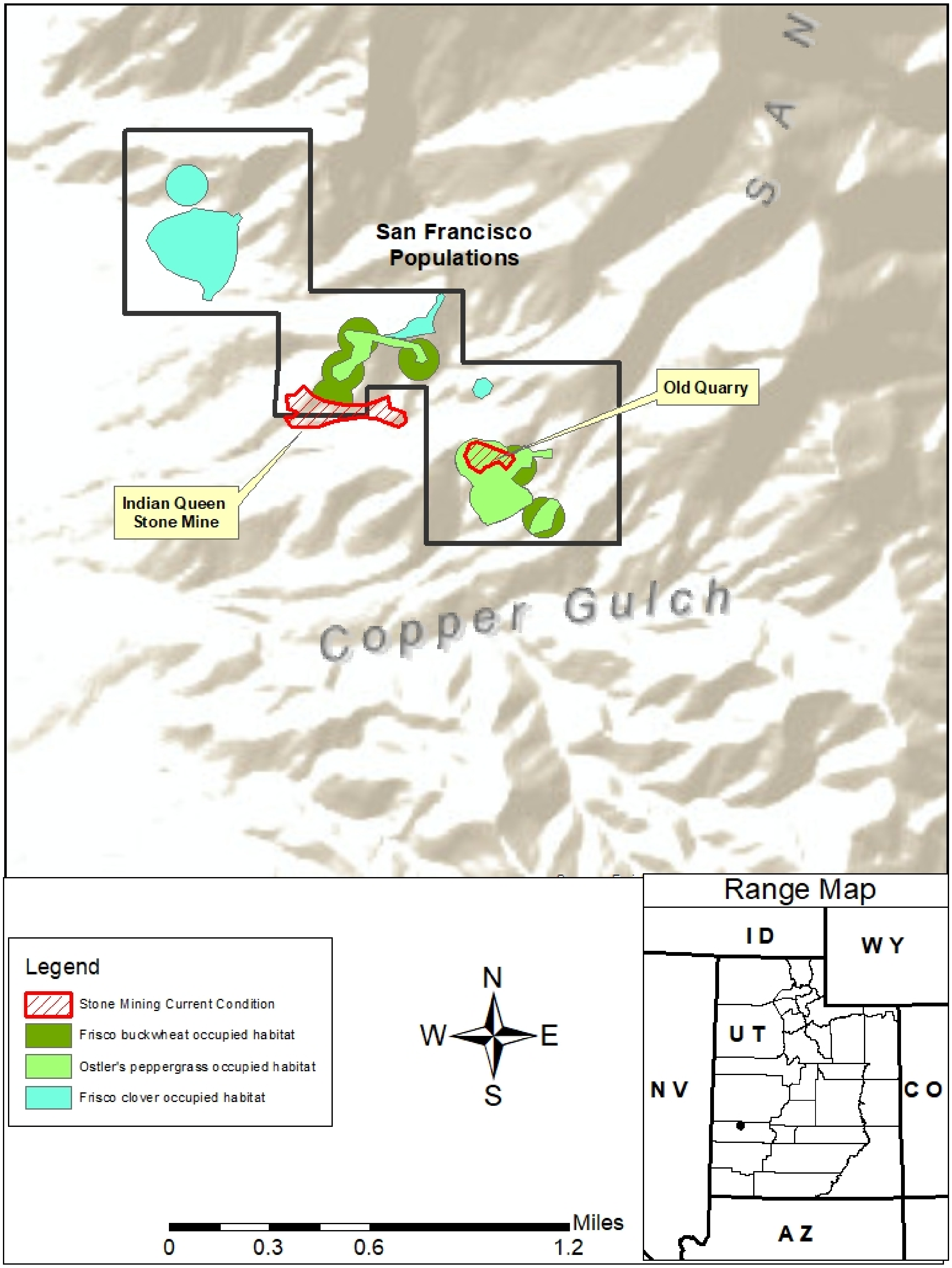

Figure 1. Current condition of stone mines and proximity to Frisco buckwheat, Ostler's peppergrass, and Frisco clover San Francisco populations. The entire permit area is depicted for the Indian Queen stone mine. The area of historical disturbance is depicted for the Old Quarry.

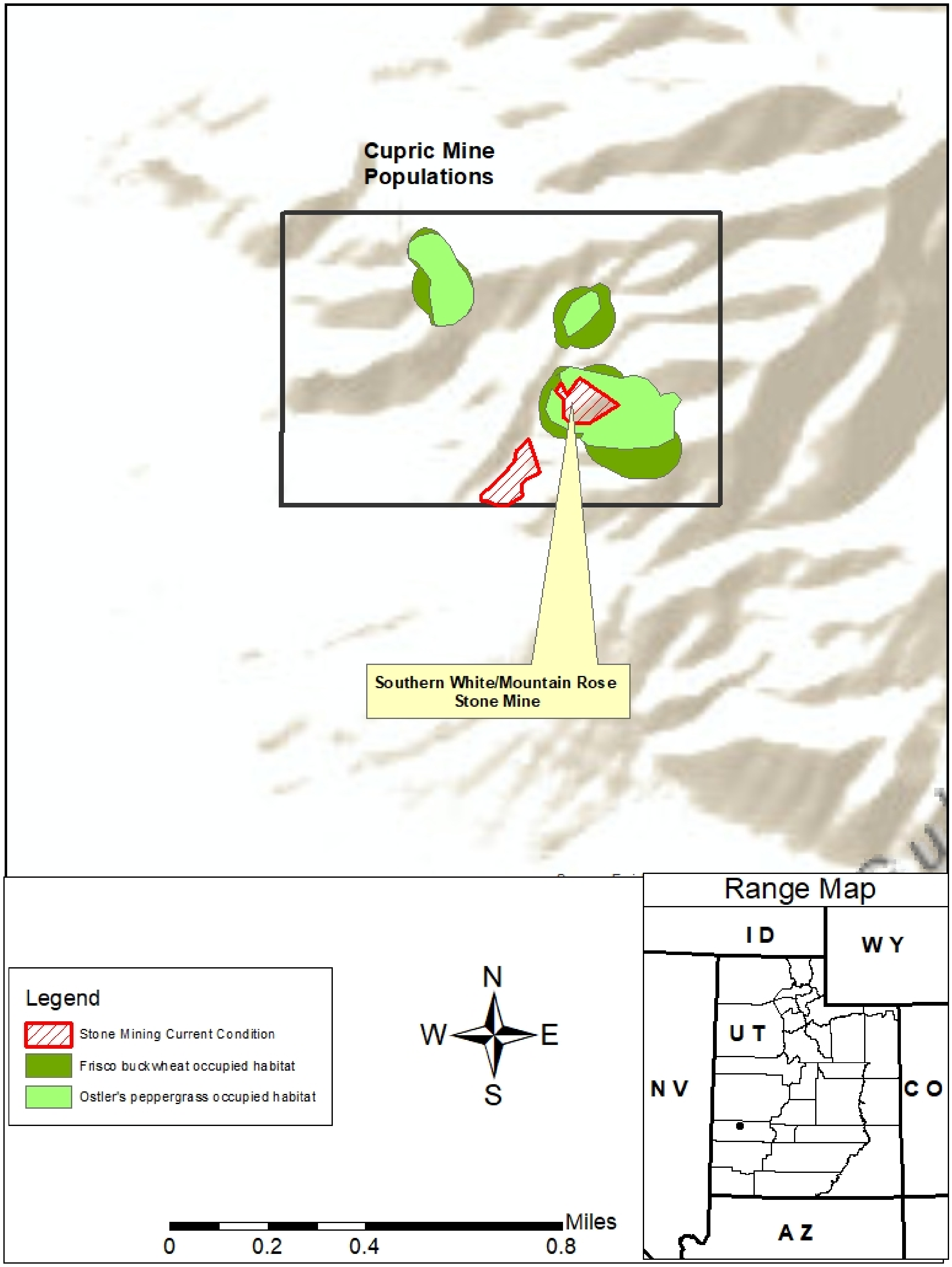

Figure 2. Current condition of the Southern White/Mountain Rose stone mine and proximity to Frisco buckwheat, Ostler's peppergrass, and Frisco clover Cupric Mine populations. The entire permit area is depicted for the Southern White/Mountain Rose stone mine.

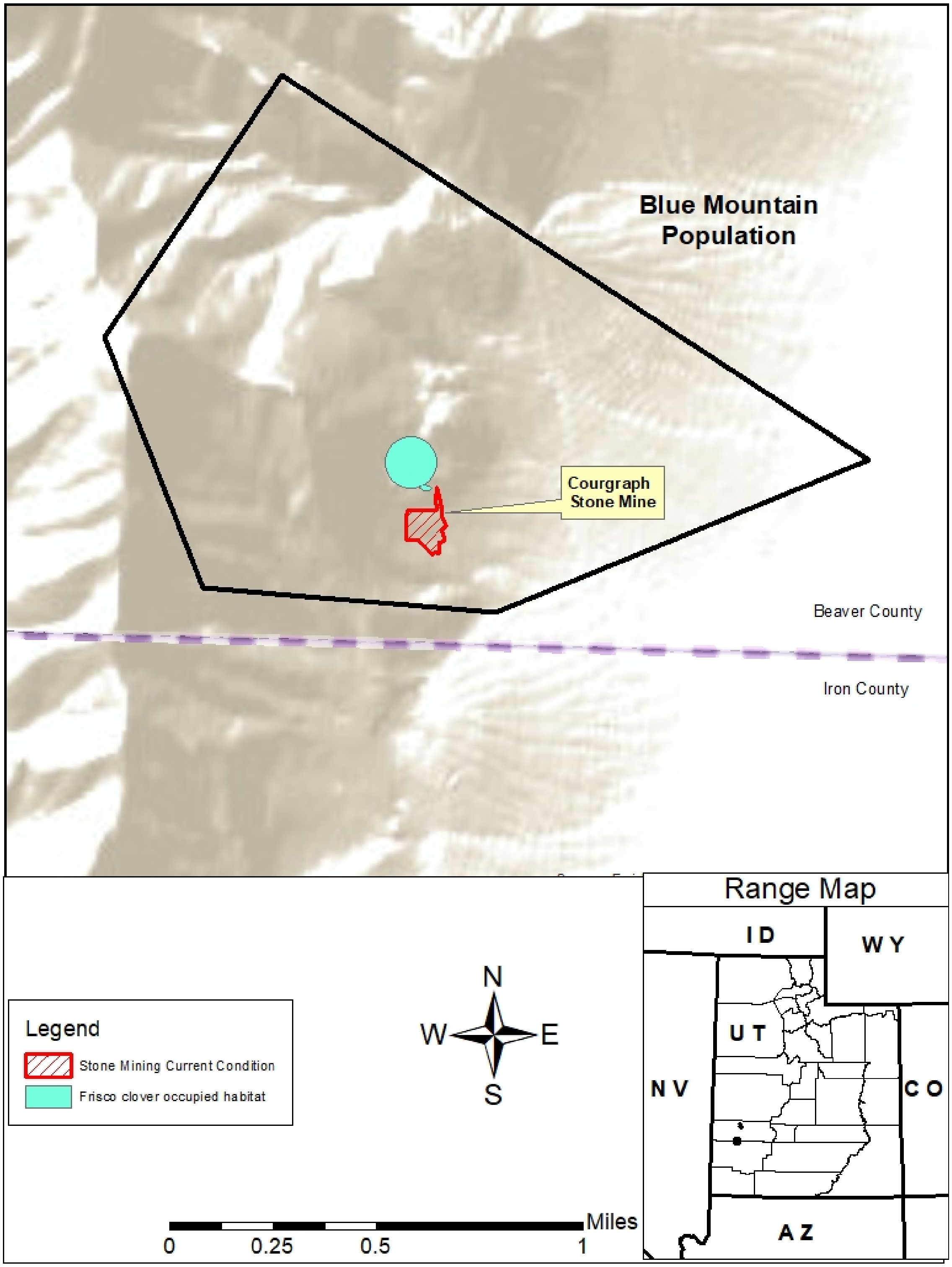

Figure 3. Current condition of the Courgraph stone mine and proximity to the Frisco clover Blue Mountain population. The entire permit area is depicted for the Courgraph stone mine.

Suitable Habitat Models Supporting the Species Status Assessment Report for Frisco buckwheat (*Eriogonum soredium*), Ostler's peppergrass (*Lepidium ostleri*), and Frisco clover (*Trifolium friscanum*)

Executive Summary

This report summarizes the methods and results of suitable habitat models created to inform the Species Status Assessment (SSA) for Frisco buckwheat, Ostler's peppergrass, and Frisco clover. We outlined several objectives for the products of this work. First, the model results should suggest locations to search for additional populations of the three species, and target future soil sampling locations. Second, the results should be used by agencies, botanists, and species experts to consider locations for possible introduction of propagated seeds or plants, and proactive conservation. Finally, the results should help us to better understand the environmental variables important to these species, and the direction of relationships as indicated by the models.

1. Introduction

Suitable habitat models (aka Species Distribution Models; hereafter SDM) have been effective at targeting sampling for rare plant species. An iterative approach integrating species distribution model development with sampling design has proven successful in several studies (Aiken et al., 2007, Guisan et al. 2006, and Le Lay et al. 2010). For this approach, models are generated based on known occurrences and the results are used to select and stratify the next year's field sampling locations. This allows the models to be validated, and for new models to be generated with improved ability to locate new plant populations. Iteration of surveying with modeling continues until model validation assessments stabilize.

SDMs have become important for identifying locations for plant species reintroduction. Ardestani et al. (2015) used MaxEnt modeling to create a SDM for three *Astragalus* sp. in Iran's rangelands to identify potential locations for reclamation projects. Adhikari, et al (2012) delineated locations where a critically endangered tree species could be reintroduced within its current home range in northeastern India. Their study also suggested environmental parameters important to the distribution of their species, and predictive of successful establishment of the species.

Understanding soil and site properties required for rare plant establishment and growth is important for successful plant propagation. Baker et al. (2016) used random forest modeling of soil properties collected in the field and spectral-topographic environmental parameters to understand soil properties for Shrubby reed-mustard [*Schoenocrambe suffrutescens* (Rollins) S.L. Welsh and Chatterly] in the Uinta Basin in UT. In their study, they linked presence and absence locations to soil and site properties, identified key soil properties predictive of plant presence and absence, as well as predicting habitat where soil properties could be surveyed to check for potential habitat.

Digital Soil Mapping (DSM) is an analogous modeling approach to SDM, whereby the distribution of soil properties and soil types are modeled based on surveyed soils in the same way species distribution is modeled based on occurrence information. DSM is helping to fill in gaps in mapped soil data, and is a promising new machine learning technique for digital soil mapping (Brungard et al. 2015; Chaney et al. 2016). Because of the tight linkage of soil properties to rare plant occurrence and absence, an iterative mapping approach using SDMs to identify sites for soil surveys could provide relevant soil data for incorporation into DSMs, which can then inform and improve predictive plant species mapping, and identify areas predicted to support plant reintroductions.

Using LiDAR data and data collected from unmanned aerial vehicles (UAV) are promising tools for targeting locations for rare plant propagation. Questad et al. (2014) used LiDAR data to model microtopographic features and develop a topographic habitat suitability model to improve the survival of planted species in a dryland landscape in Hawaii. Because LiDAR and UAV data is expensive to collect, using a SDM based on existing plant occurrences to prioritize these surveys would reduce the cost of data collection, which could potentially improve restoration success.

2. Methods

2a. Study Area

The study area consists of the model processing boundary generated by buffering the known survey locations of Frisco endemic species by 50 miles and creating a minimum bounding geometry envelope from this polygon (MCH; Figure 1). The 50 mile distance was found by calculating half the distance between the furthest two survey points from each other. This created a polygon covering a large area within eight western south-central Utah counties and two eastern south-central Nevada counties within the basin and range physiographic province. This boundary was used for clipping the environmental variable raster data and was the extent used in initial model processing. The final model will be subset by species bounding boxes to much smaller priority study areas delineated based on expert opinion and the MCH of current survey points (Figure 1). These smaller areas will be more representative of likely potential habitat and will encompass an area where the model is most predictive.

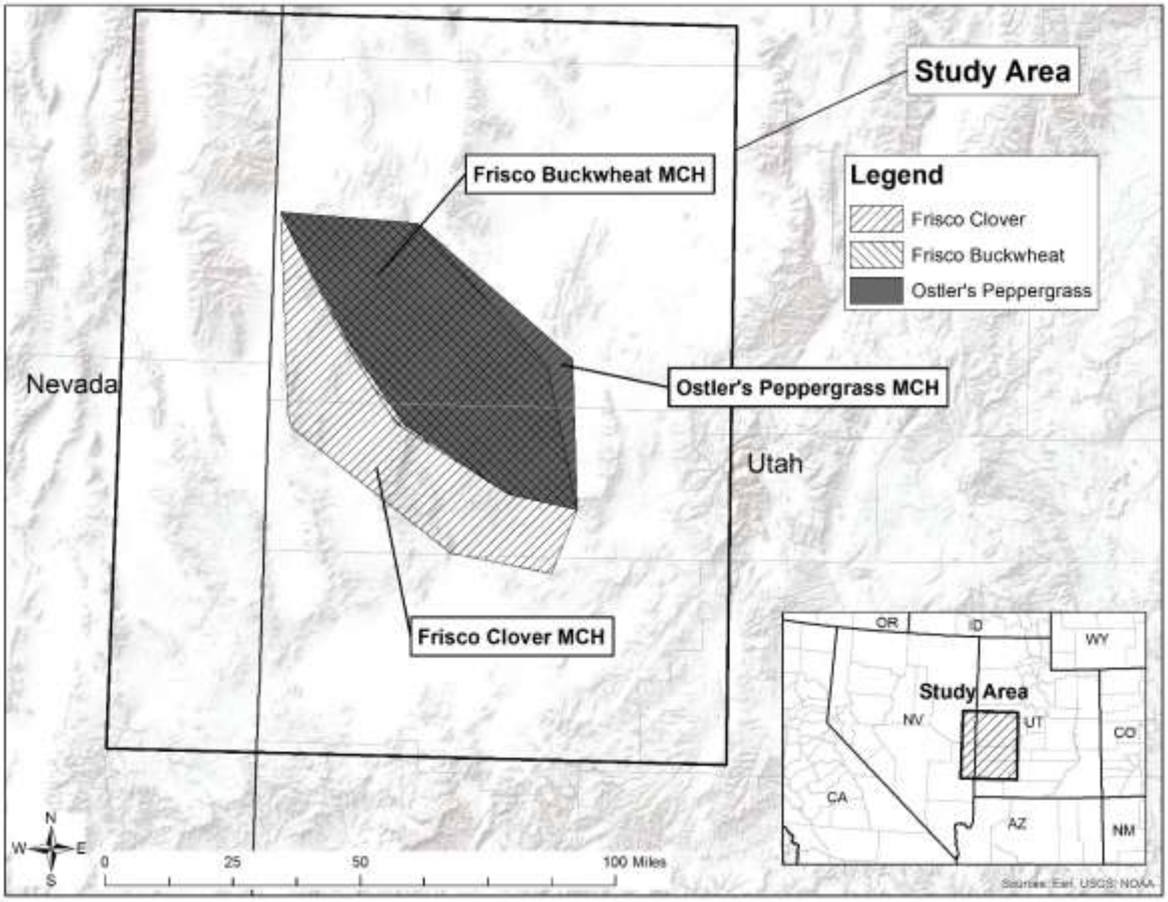

Figure 1. Model processing study area and minimum convex hulls (MCH) of survey locations for each species.

2b. Presence and Absence Records

I used 67 presence records for Frisco buckwheat, 39 presence records for Ostler's peppergrass, 83 presence records for Frisco clover, and 148 presence records for Frisco endemic species together for suitable habitat modeling input. These points were compiled from data provided by the State of Utah and the U.S. Fish and Wildlife Service (USFWS) UT Ecological Services field office in the spring and summer of 2017. See Section 1.1 Occurrence Data in "U.S. Fish and Wildlife Service. 2017. Species status assessment report for Frisco buckwheat (*Eriogonum soredium*), Ostler's peppergrass (*Lepidium ostleri*), Frisco clover (*Trifolium friscanum*). Utah Ecological Services Field Office, Salt Lake City, Utah. 100 pages." Points were generalized so that no more than one point occupied each 30-m pixel, corresponding to the resolution of the available environmental variable raster data. This process, which reduces spatial autocorrelation of nearby points, removed 28 Frisco buckwheat points, 24 Ostler's peppergrass points, and nine Frisco clover points.

True absence data was available in the data provided, but I was concerned about using it for two reasons. First, it was difficult to know if recorded absences indicated absence because of true unsuitability of the habitat, or simply indicated that the species had not yet been able to spread to these areas, or had been extirpated prior to sampling. Second, I could not be sure that these absences were representative of the variability of the surrounding environment, or might instead be biased by convenience sampling to areas nearby targeted presence locations. Because of these concerns, I opted to test the performance of surveyed absence data by comparing the cross-validation results of models fitted using these absence points with models fitted with background absences created using the function pseudo.absence (Evans 2017). Pseudo.absence generates random samples based on the density estimate of known locations and minimizes the mean-square error using the methods of Berman and Diggle (1989). The MCH of all sampling, including the provided absence points, was used for the maximum extent of generated pseudo absence points. For pseudo absences, I generated three times the number of presence points for each species to adequately cover the area of the MCH, but avoid zero inflation. For comparison, I also subsampled the provided true absences so that each species was modeled with three times the number of true absences as presence points. I used a kernel density function to select true absences that were spatially balanced across the sampled area.

2c. Environmental Variables

I initially considered 31 potential environmental covariates based on their potential to be predictive of plant occurrence from conversations with species experts (Dr. Janis Boettinger and Jennifer Lewinsohn, personal communication, January 27 and March 2, 2017). However, I wanted to limit the number of environmental predictors used for modeling to approximately one per ten presence records to avoid model overfitting (Breiner et al. 2015). To reduce the number of predictors, I used a four step process for each species. First, I reviewed the predictor data for each species visually. For some variables, I found that nearly all presence points had the same predictor variable value (Table 1). Specifically, this occurred when predictors were nominal variables that had been geoprocessed for representation as a percent cover value and indicated zero cover. In other words, there was no association with the variable in question to species presence. To prevent statistical issues with complete or quasi-complete separation (Allison 2008), these predictors were culled from the initial set of predictors. However, they may be useful in the future for stratifying survey locations into likely presence/absence locations. Next, I included all remaining potential covariates and ran a function that identified and removed multi-colinear variables using QR matrix decomposition (Evans et al. 2011). Next, I identified variables that were correlated with a correlation coefficient ±0.7 or greater and removed one of each correlated variable based on a rule where I retained at least one variable from each major environmental class, e.g., solar, topographic, geologic, spectral. Finally, with the remaining covariates I used methods unique to each of the individual modeling methods to remove the necessary variables to equal the number of desired covariates for the species being evaluated. These methods will be described in the Modeling Procedures section of this document.

Variable	Description
G_Eral2	Geologic Era, Devonian
G_Eral12	Geologic Era, Quaternary
G_Eral13	Geologic Era, Silurian
G_Eral14	Geologic Era, Tertiary
aster_21pc	Ferrous or coarse-grained ferric iron (may include oxidized basalts, fire ash, some moist soils, and any blue/green rocks)

Table 1. Environmental variables removed due to nearly perfect negative congruence with presence data.

2d. Modeling Procedures and Predictive Mapping

To compare model performance using true absence points versus using pseudo absence points I fit random forests (RF) and maximum entrophy (MAX) test models for each species with the two types of absence points, and calculated their accuracy using 10-fold cross validation. I compared the metrics for sensitivity and TSS to determine which points produced a model emphasizing positive prediction and overall prediction. I used the results from this test to determine which absence data I should use to fit the remaining model methods for each species.

I used an ensemble modeling approach with five modeling techniques to generate models, predictive maps, and an ensemble concordance map for each species. The statistical package R (R Core Team 2017) was used for all modeling. The models used were: 1.) random forests, 2.) generalized linear models (GLM), 3.) generalized additive models (GAM), 4.) boosted regression trees (BRT), and 5.) maximum entrophy models. For all modeling procedures, I began with the set of predictors for each species that remained after performing QR matrix decomposition and removing highly correlated variables as described above.

For RF modeling, I used a model selection function by Murphy et al. (2010) to select the best model using as close to the desired number of covariates as possible for each species. This routine evaluates the number of times a variable is selected greater-than or equal-to the defined threshold for the global and local (class level) importance. This allows one to evaluate if a given variable is important to the overall model or specific classes. For classification, model selection is based on smallest out-of-bag (OOB) error and smallest maximum within class error. For the model selection process and the final model, I fitted random forest models by growing 501 trees with all presence points and the generated pseudo absence points.

GLM model predictors were subset using the glmulti function from Calcagno (2013). This function automatically compares all possible glm models and finds the best model predictors in terms of AIC. I then ranked the chosen variables from the best model in terms of importance, and subset out the top predictors to equal the number of desired covariates for each species. GLM was then fit using a binomial distribution and a logistic link function with these covariates. When models exhibited complete or quasi-complete separation as indicated by the error "fitted probabilities numerically 0 or 1 occurred", I instead ran Bayesian linear regression with the same parameters, using the function bayesglm from Gelman, A. and Su, Y. (2016).

GAM model predictors were selected by running an initial linear model with GAM and then selecting the top predictors based on the f statistic p-value equal to the number of desired covariates for each species. Next, GAM models were fit using a binomial distribution and a logistic link function to test the fit of smoothers four, five and six. The model with smoothers providing the highest fit was then run.

For BRT modeling, I fit a model using the initial set of covariates to find the relative influence of each predictor. I then subset out the top predictors based on the highest relative influence to equal the number of desired covariates for each species. BRT was run using a tree complexity of 3, a bag fraction of 0.75, and 10 folds for all species. Learning rate was adjusted as needed based on the species being modeled. A warning message indicating overfitting and complete separation occurred for some species; However, I ignored these messages based on the suggestion by Coadou 2013 that overfitting in BRT wouldn't influence the boosting output, as these trees contribute little to the final model.

MAX models were created by first limiting the number of predictor variables using ENMeval functions from Muscarella et al. (2014) to extract percent contribution (Phillips, 2006) from a maximum entropy model. I sorted the predictors based on their percent contribution, and then culled predictors to the desired number of covariates for each species. For the model selection process and the final model, I fitted MAX models with all presence points and the generated pseudo absence points. I used all default settings available in the dismo package (Hijmans et al. 2017) for the maxent function.

For all model types, I generated a presence/absence threshold value based on maximizing Kappa using the methods of Freeman and Moisen (2008). Because our goals were primarily to target locations that could be surveyed to find new populations, or to propagate plants, maximizing kappa was chosen as the optimal method to classify presence. The Kappa statistic summarizes all the available information in the confusion matrix and measures the proportion of correctly classified units after accounting for the probability of chance agreement. The threshold statistic was used to perform resubstitution validation and create class maps for each species. I first generated predicted probability maps based on all five models for all species, and then classified these into bivariate presence/absence maps using the max Kappa threshold. I used the Raster Calculator in ArcGIS 10.5 to add all five classified maps together for each species to create final concordance maps. These maps include values 0 – 5, and show areas where no model through all five models predict species occurrence.

2e. Model Evaluation

I quantified the accuracy of each model using five resubstitution measures of accuracy, and as described above, by maximizing kappa as the threshold to measure accuracy against. Statistics measured were: sensitivity, specificity, area under the curve (AUC), percent correctly classified (PCC), and true skills statistic (TSS).

Additionally, I calculated 10-fold cross-validation (Fielding and Bell 1997) for all models except for ensemble models BRT and RF. K-fold validation tests the model by partitioning the data into random sets of K-groups. Each group is then evaluated by fitting the model with K-1 sets of the data, and then testing the remaining sample for fit. Final accuracy statistics are then averaged to produce validation estimates. Accuracy statistics are reported for ensemble models, BRT and RF, from partitioning cross validation calculations internal to model fitting.

2f. Multivariate Environmental Similarity Surface Evaluation

I evaluated the multivariate environmental similarity surface (MESS) for each model predictor for each species. The MESS calculation represents how similar a cell in the environmental predictor's surface is to the set of values for the same predictor at presence locations (Elith et al. 2010). Values in the output surface that are positive are within the extrapolation range, while negative values are outside of the predictive range and are considered non-extrapolation areas. I classified MESS output for each predictor into a binary surface representing extrapolation (0) and non-extrapolation areas (1), and then subtracted the classified non-extrapolation areas of each predictor used in each of the five models from the final model concordance surface to get a surface showing the range of areas from no environmental variables outside predictable values (1s) to areas with all environmental variables outside predictable values (0 to –n).

I then added the areas within the extrapolation range (1s) for all five models together to generate a final MESS surface for each species. These maps, which provide a more limited prediction of suitable habitat, were used to suggest areas for species propagation and proactive conservation. Additionally, a surface was created showing the number of predictors outside of the environmental range across the landscape for a species, as well as output for the Most Dissimilar Variable (MoD) surface, which describes what variable is most limiting for the species across the landscape.

2g. Niche Similarity Comparison by Species

I compared the distribution of values for environmental predictors found to be important during model fitting by presence and pseudo absence locations for each species using bean plots. These plots illustrate how the three species are similar or differ in the ecological niches they currently occupy and in pseudo absence locations.

3. Results

3a. Comparison of True Absence with Background Absences

Comparison of 10-fold cross-validation results from models generated with true absence and those generated with pseudo absence background points showed that models fit using pseudo absence points performed consistently better, validating the assumption that the provided surveyed absence points could be spatially biased, and that the consequence of selecting from a broader range of background environments could enhance the ability of the models to discriminate among areas potentially suitable and not suitable habitat. For Frisco buckwheat, RF and MAX test models performed much better using pseudo absences for tss, while sensitivity performed better with RF, and just as well with MAX (Table 2).

	RF		MAX	
	tss	sensitivity	tss	sensitivity
Pseudo Absences	0.836	0.851	0.851	0.866
True Absences	0.781	0.806	0.791	0.866

Table 2. Comparison of 10-fold cross-validation results for Frisco buckwheat models fit with pseudo absence data and true absence data.

For Ostler's peppergrass, RF and MAX models fit with pseudo absence data performed better using measures of both tss and sensitivity (Table 3.)

	RF		MAX	
	tss	sensitivity	tss	sensitivity
Pseudo Absences	0.940	0.949	0.957	0.974
True Absences	0.821	0.846	0.915	0.923

Table 3. Comparison of 10-fold cross-validation results for Ostler's peppergrass models fit with pseudo absence data and true absence data.

The comparisons for Frisco clover showed much better tss and sensitivity results for RF and MAX models fit with pseudo absences (Table 4). The differences between models fit with the two types of absence data for Frisco clover was much greater than those seen in either Frisco buckwheat or Ostler's peppergrass.

	RF		MAX	
	tss	sensitivity	tss	sensitivity
Pseudo Absences	0.771	0.831	0.811	0.916
True Absences	0.562	0.614	0.514	0.687

Table 4. Comparison of 10-fold cross-validation results for Frisco clover models fit with pseudo absence data and true absence data.

When Frisco endemic species are modeled together, RF and MAX models fit with pseudo absences points also perform much better using measures of both tss and sensitivity (Table 5).

	RF		MAX	
	tss	sensitivity	tss	sensitivity
Pseudo Absences	0.842	0.872	0.793	0.818
True Absences	0.547	0.601	0.581	0.709

Table 5. Comparison of 10-fold cross-validation results for Frisco endemic species models fit with pseudo absence data and true absence data.

3b. Model Performance

Internal and cross validation results show that models for all three species and all Frisco endemic species together performed very well. Table 6 summarizes model performance by each species for all model types. Environmental predictors that were important to each species and for all species together are described below.

Species	Model	Type	PCC	Sensitivity	Specificity	AUC	TSS
Frisco buckwheat	BRT	Internal	1.00	1.00	1.00	1.00	1.00
		Cross Validation	0.96	0.93	0.98	0.98	0.90
	GAM	Internal	1.00	1.00	1.00	1.00	1.00
		Cross Validation	0.94	0.85	0.98	0.98	0.83
	LR	Internal	0.97	0.93	0.99	0.99	0.91
		Cross Validation	0.97	0.88	1.00	0.98	0.88
	MAX	Internal	0.97	0.91	0.99	0.99	0.90
		Cross Validation	0.96	0.87	0.99	0.99	0.85
	RF	Internal	0.95	0.85	0.99	0.98	0.84
		OOB	0.93	0.85	0.96	0.98	0.81
Ostler's peppergrass	BRT	Internal	1.00	1.00	1.00	1.00	1.00
		Cross Validation	0.99	0.97	0.99	1.00	0.97
	GAM	Internal	1.00	1.00	1.00	1.00	1.00
		Cross Validation	0.96	0.97	0.96	0.99	0.93
	LR Bayes	Internal	0.97	1.00	0.97	0.98	0.97
		Cross Validation	0.97	0.97	0.97	0.98	0.94
	MAX	Internal	1.00	1.00	1.00	1.00	1.00
		Cross Validation	0.98	0.97	0.98	1.00	0.96
	RF	Internal	0.99	0.97	0.99	1.00	0.97
		OOB	0.98	0.95	0.99	1.00	0.94
Frisco clover	BRT	Internal	0.97	0.98	0.96	0.99	0.94
		Cross Validation	0.90	0.84	0.92	0.96	0.77
	GAM	Internal	0.97	0.93	0.99	1.00	0.92
		Cross Validation	0.93	0.90	0.94	0.96	0.84
	LR	Internal	0.93	0.99	0.91	0.97	0.90
		Cross Validation	0.91	0.98	0.89	0.96	0.87
	MAX	Internal	0.94	0.95	0.94	0.98	0.89
		Cross Validation	0.90	0.92	0.90	0.96	0.81
	RF	Internal	0.92	0.87	0.93	0.97	0.80
		OOB	0.91	0.83	0.94	0.97	0.77
All Three	BRT	Internal	1.00	1.00	1.00	1.00	1.00
		Cross Validation	0.94	0.86	0.96	0.98	0.82
	GAM	Internal	0.96	0.95	0.97	0.99	0.92
		Cross Validation	0.91	0.74	0.97	0.95	0.71
	LR	Internal	0.93	0.84	0.96	0.97	0.80
		Cross Validation	0.92	0.84	0.95	0.96	0.79
	MAX	Internal	0.96	0.91	0.98	0.99	0.89
		Cross Validation	0.94	0.82	0.98	0.97	0.79
	RF	Internal	0.95	0.88	0.97	0.98	0.85
		OOB	0.95	0.87	0.97	0.98	0.84

Table 6. Internal and 10-fold cross validation results for five model types by species.

i. Frisco Buckwheat

Frisco buckwheat had 67 presence records and 201 pseudo absences. For all models, I used the top seven predictors (see Appendix 1) chosen by the model selection methods described above. Table 7. a. shows these predictors, and how often they were used for modeling. Only three predictors, LS_SR_NI52, LS_SR_NI57, and aster_6pc were used in all five model types. Table 7 b. summarizes predictors from GLM and GAM that were found to be significant and the direction of the relationship, and important predictors from BRT, MAX, and RF.

Predictor	Number of Models
LS_SR_NI52	5
LS_SR_NI57	5
aster_6pc	5
G_Eral14pc	4
SSW_Evans	3
G_Eral7pc	3
LS_SR_B_5	2
IMI_Evans	2
LCurvEvans	2
LS_SR_NI32	1
SEI_Evans	1
ASolDifYr	1
aster_7pc	1

a.

Significant Predictors & Direction	Important Predictors
ASolDifYr/+	aster_6pc
aster_6pc/+	LS_SR_NI57
G_Eral14pc/+	LS_SR_NI52
G_Eral7pc/+	G_Eral14pc
LS_SR_B_5/+	SSW_Evans
LS_SR_NI32/+	
LS_SR_NI57/+	
LS_SR_NI52/-	

b.

Table 7 a. Frisco buckwheat predictors (Appendix 1) and number of times used in a model. 7 b. Frisco buckwheat GLM and GAM significant predictors with relationship direction, and most important predictors from BRT (relative importance), MAX (variable importance), and RF models (Gini importance).

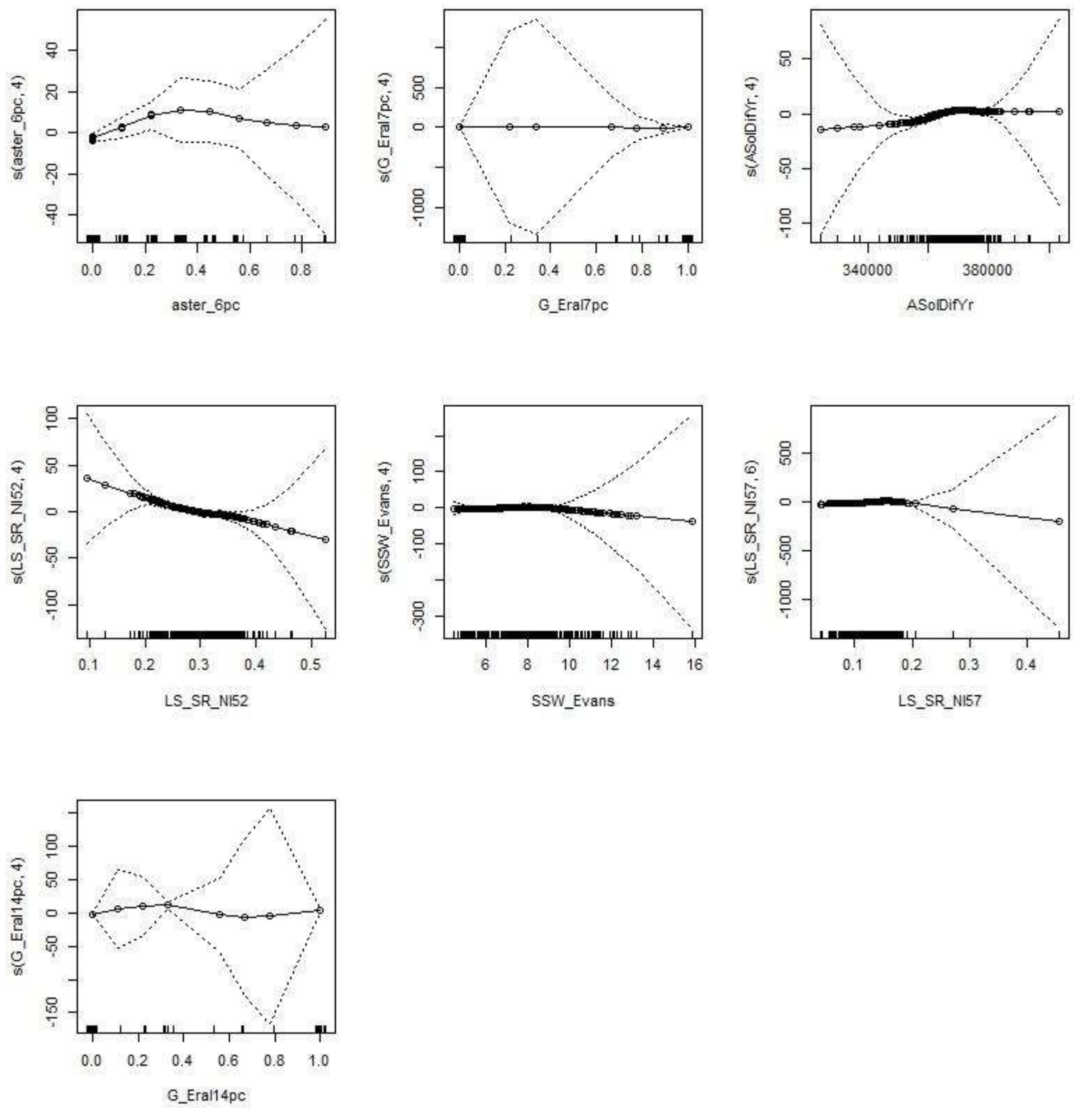

Figure 2. Frisco buckwheat GAM predictors and smoothing.

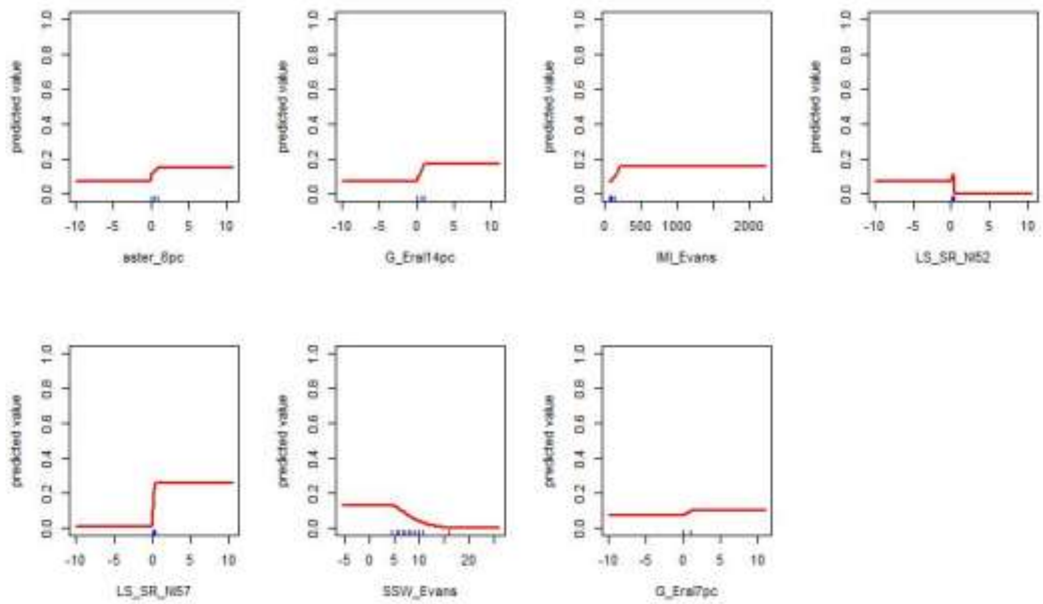

Figure 3. Frisco buckwheat MAX predictor plots.

ii. Ostler's Peppergrass

Ostler's peppergrass had only 39 presence records and 117 pseudo absences. I used four predictors (see Appendix 1) for all models selected using methods described above except for GAM, which used two. One predictor, LS_SR_NI57, was used in all five models. Table 8 a. and b. shows how many models each predictor was used in, significant predictors and relationship direction from GLM and GAM, and important predictors from BRT, MAX, and RF.

Predictor	Number of Models
LS_SR_NI57	5
caco3_m0_5	4
aster_6pc	3
LS_SR_NI52	2
LS_SR_NI32	1
aster_7pc	1
IMI_Evans	1
G_Eral14pc	1

a.

Significant Predictors & Direction	Important Predictors
LS_SR_NI_32/-	caco3_m0_5
LS_SR_NI_57/+	LS_SR_NI57
	aster_6pc
	aster_7pc
	LS_SR_NI52

b.

Table 8 a. Ostler's peppergrass predictors (Appendix 1) and number of times used in a model. 8 b. Ostler's peppergrass GLM and GAM significant predictors with relationship direction, and most important predictors from BRT (relative importance), MAX (variable importance), and RF models (Gini importance).

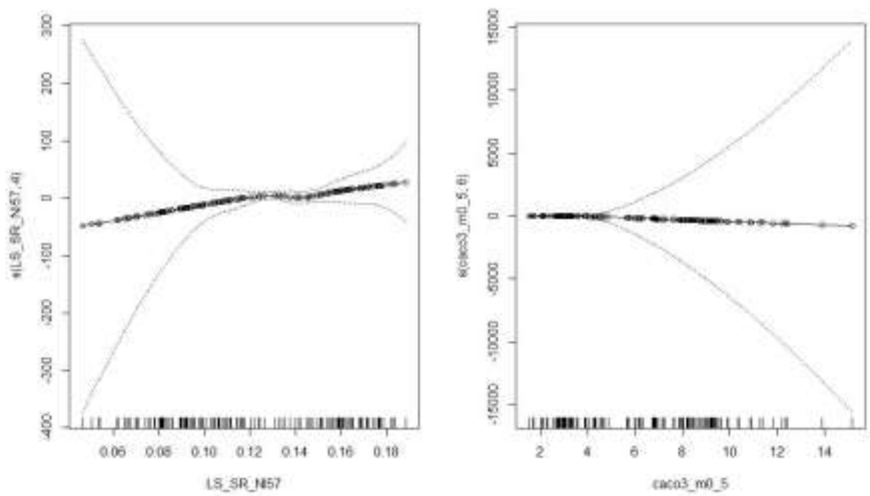

Figure 4. Ostler's peppergrass GAM predictors and smoothing.

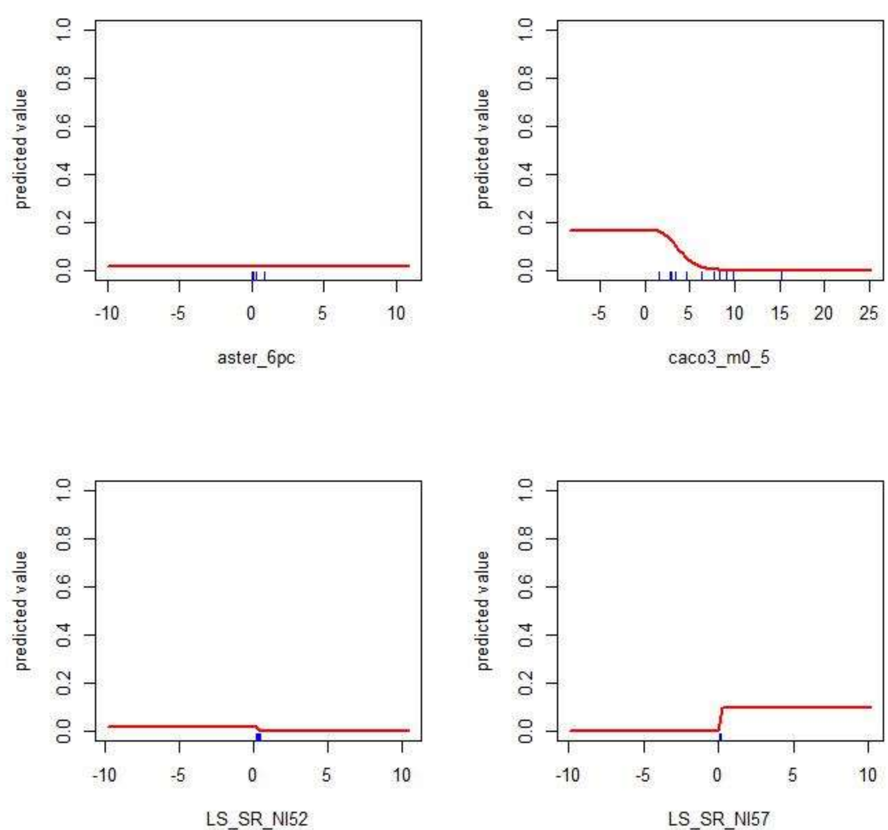

Figure 5. Ostler's peppergrass MAX predictor plots.

iii. Frisco Clover

Frisco clover had 83 presence records and 249 pseudo absences. I used eight predictors (see Appendix 1) for all models selected using methods describe above. Four predictors were used in all five models, G_Eral7pc, LS_SR_NI32, aster_6pc, and slope_dg. Table 9 a. and 9 b. shows how many models each predictor was used in, significant predictors and relationship direction from GLM and GAM, and important predictors from BRT, MAX, and RF.

Predictor	Number of Models
G_Eral7pc	5
LS_SR_NI32	5
aster_6pc	5
slope_dg	5
LS_SR_B_5	4
G_Eral13pc	4
aster_7pc	4
aster_21pc	2
LCurvEvans	2
SSW_Evans	1
ASolDifYr	1
LS_SR_NI57	1
SEI_Evans	1

a.

Significant Predictors & Direction	Important Predictors
aster_21pc/+ -	slope_dg
aster_6pc/+	LS_SR_NI32
G_Eral13pc/+	G_Eral7pc
G_Eral7pc/+	aster_6pc
LS_SR_B_5/+	aster_7pc
LS_SR_NI32/-	
LS_SR_NI57/+	

b.

Table 9 a. Frisco clover predictors (Appendix 1) and number of times used in a model. 9 b. Frisco clover GLM and GAM significant predictors with relationship direction, and most important predictors from BRT (relative importance), MAX (variable importance), and RF models (Gini importance).

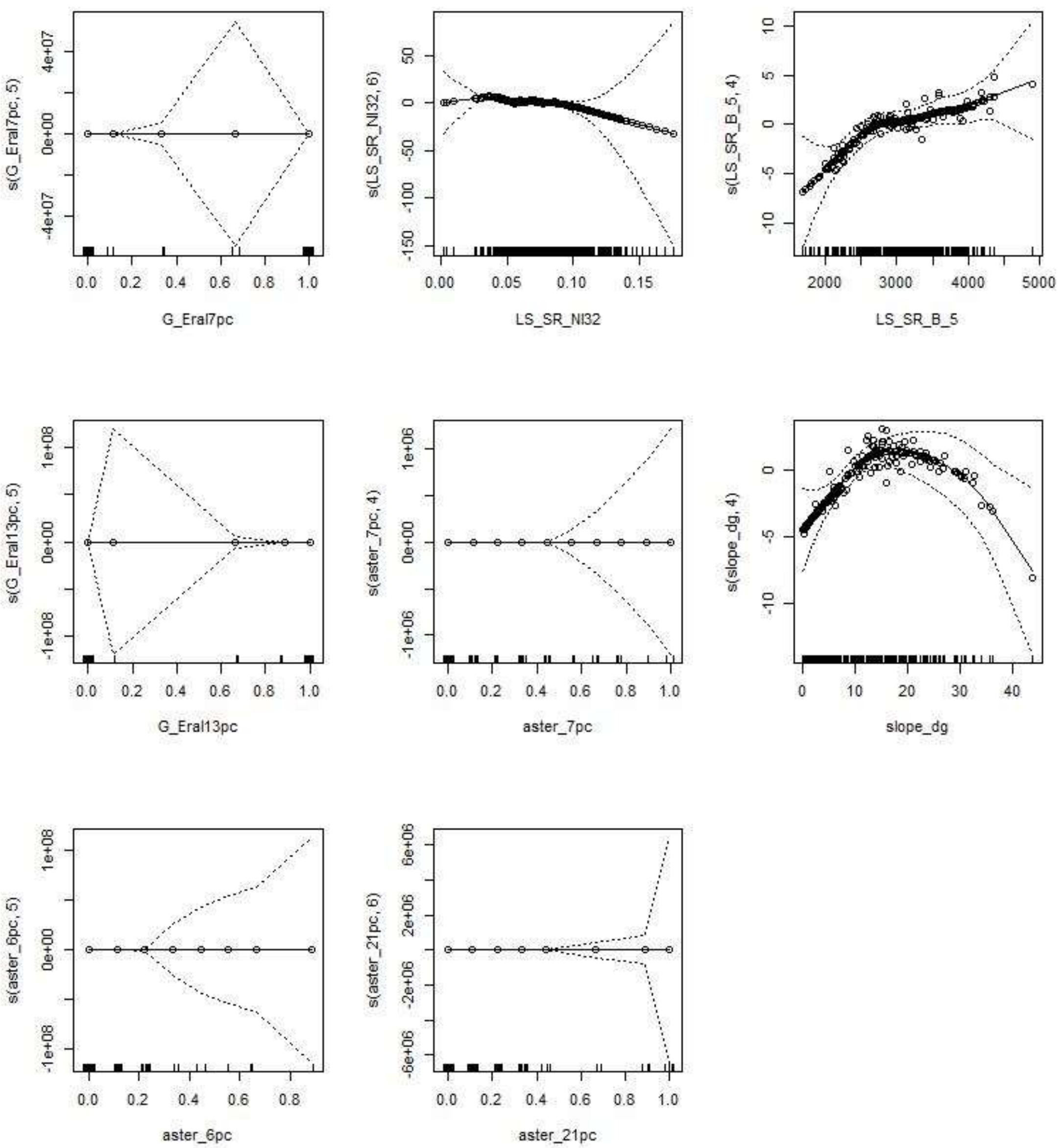

Figure 6. Frisco clover GAM predictors and smoothing.

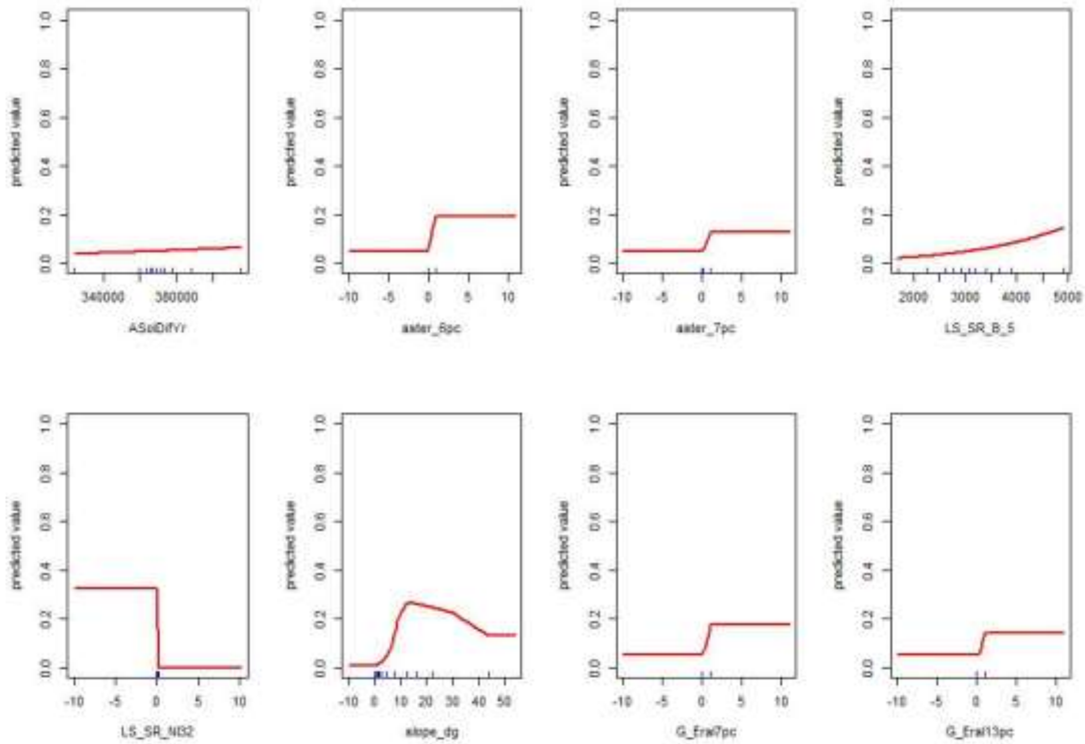

Figure 7. Frisco clover MAX predictor plots.

iv. Three Frisco Endemic Species

There were 148 presence records and 444 pseudo absences for Frisco endemic species together. I used 15 predictors for all models, except for GAM and RF, which used 13 and 14, respectively. Several predictors were used in all five models, as shown in table 10 a. Table 10 b. shows significant predictors, the relationship direction, and important predictors.

Predictor	Number of Models
slope_dg	5
LS_SR_NI32	5
ASolDifYr	5
aster_6pc	5
LS_SR_NI52	5
aster_7pc	5
Elev30m	5
G_Eral7pc	5
SSW_Evans	4
LS_SR_NI57	4
LS_SR_B_7	4
SEI_Evans	3
G_Eral14pc	3
aster_21pc	3
G_Eral12pc	3
LCurvEvans	2
IMI_Evans	2
G_Eral13pc	2
HLI_Evans	2

a.

Significant Predictors & Direction	Important Predictors
ASolDifYr/-	LS_SR_NI57
aster_21pc/+	LS_SR_NI32
aster_6pc/+	G_Eral7pc
aster_7pc/+	aster_6pc
Elev30m/+	LS_SR_NI52
G_Eral13pc/+	aster_7pc
G_Eral14pc/+	slope_dg
G_Eral7pc/+	Elev30m
IMI_Evans/+	
LS_SR_NI52/-	
LS_SR_NI57/+	
slope_dg/-	
SSW_Evans/-	

b.

Table 10 a. All Frisco endemic species together predictors (Appendix 1) and number of times used in a model. 10 b. Frisco endemic species together GLM and GAM significant predictors with relationship direction, and most important predictors from BRT (relative importance), MAX (variable importance), and RF models (Gini importance).

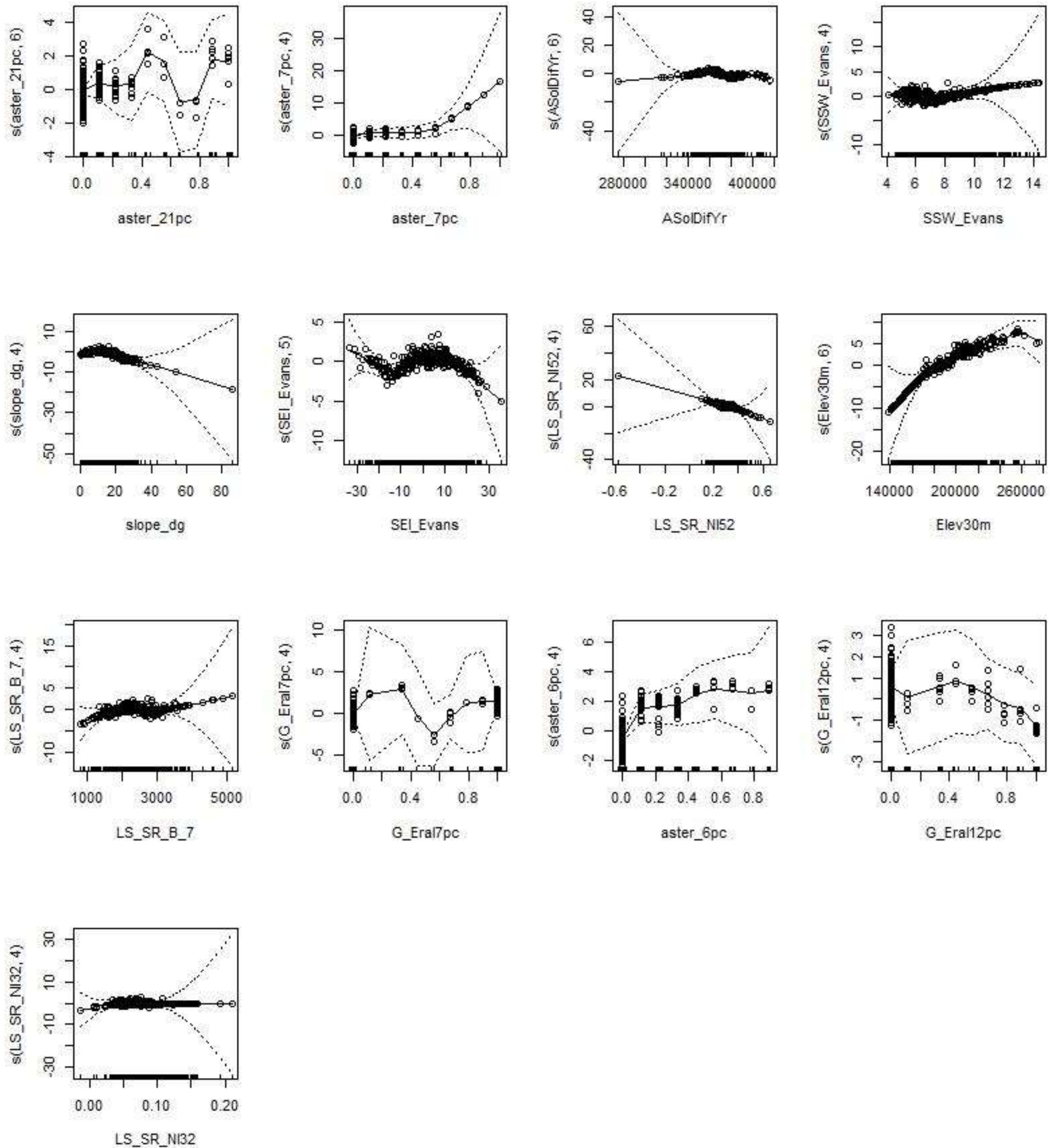

Figure 8. Frisco endemic species GAM predictors and smoothing.

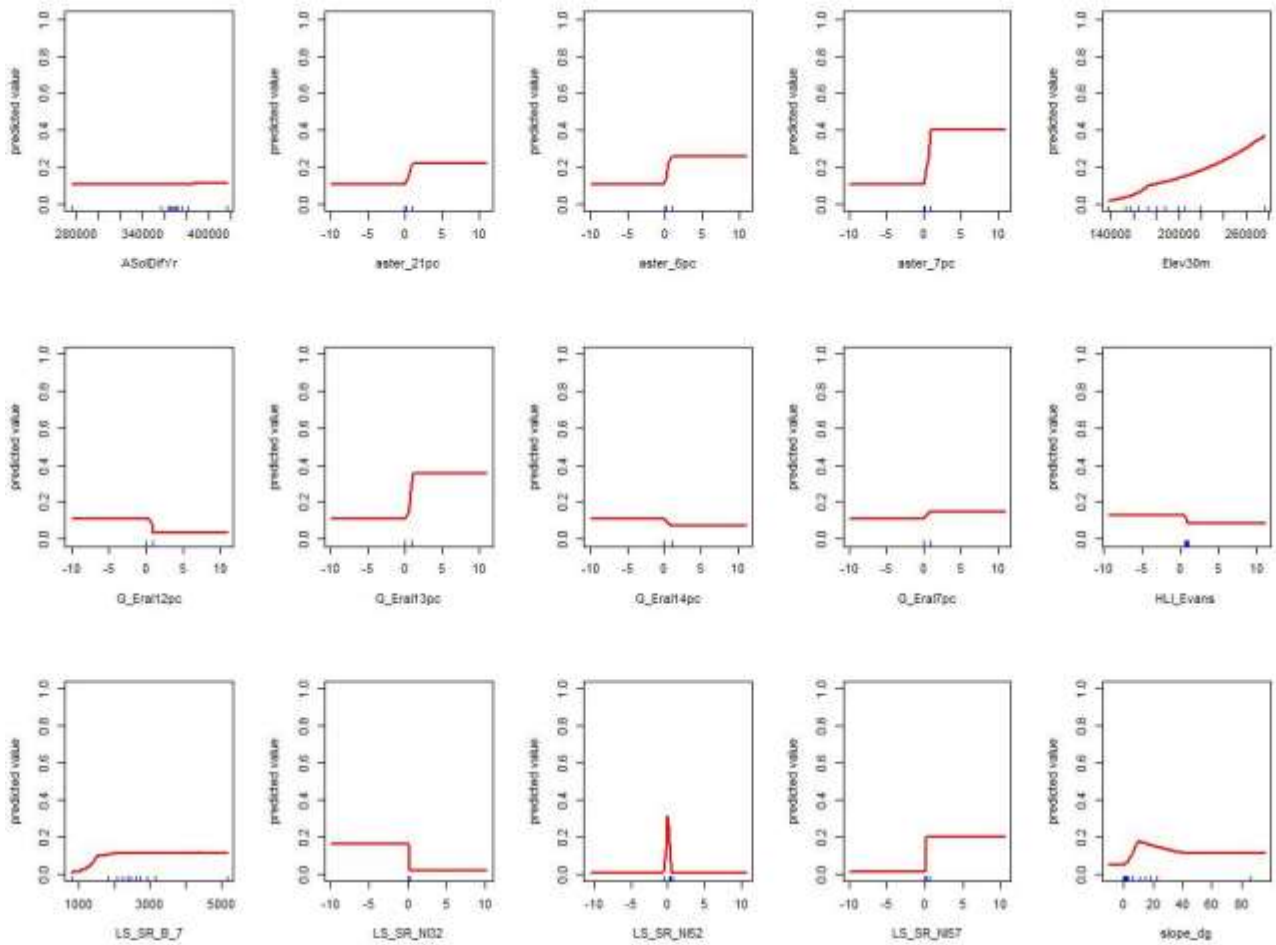

Figure 9. Frisco endemic species MAX predictor plots.

3c. Habitat Suitability

i. Frisco Buckwheat

Within the model processing area, 8,802 hectares of Frisco buckwheat suitable habitat were predicted by all five models; 32,358 hectares were predicted by four models; and 324,974 hectares were predicted by one, two, or three models. Hectares were calculated by summing the number of cells predicted and multiplying this number by the number of hectares per 900-m^2 cell. It is important to note that this value is an extrapolation, and that the model is not predicting that plants will occur across all of the area in each predicted cell, but instead predicts that the cell will be occupied.

Within the San Francisco Mountains type locality, 413 hectares of suitable habitat were predicted by concordance of all five models. Figure 10 shows this area, as well as additional mountainous localities predicted to have suitable habitat by all five models. Table 11 summarizes the hectares of suitable habitat found in each mountainous area.

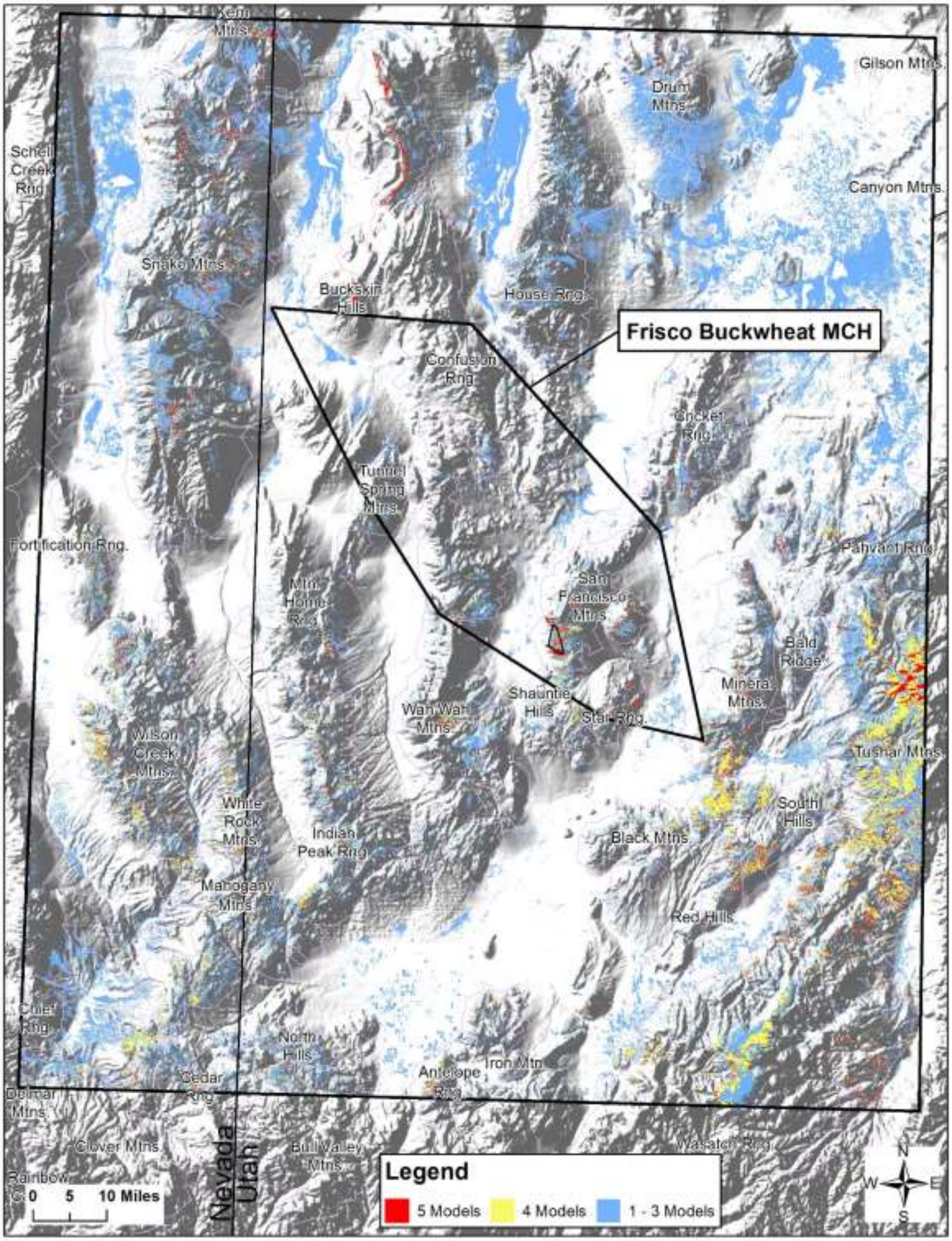

Figure 10. Frisco buckwheat suitable habitat model concordance for five models. The large black rectangle shows the model processing area, while the small polygon within the Frisco buckwheat Minimum Convex Hull (MCH) shows the extent of surveyed presence locations.

Locality	Hectares Predicted by all 5 Models
Tushar Mountains	3,657
Wasatch Range	1,159
Snake Mountains	620
San Francisco Mountains	413
Black Mountains	374
Confusion Range	360
Mineral Mountains	327
Wilson Creek Mountains	299
South Hills	157
Indian Peak Range	138
Pahvant Range	113
Mahogany Mountains	105
Kern Mountains	103
Buckskin Hills	88
Wah Wah Mountains	85
Star Range	84
Fortification Range	82
White Rock Mountains	76
Antelope Range	75
Cricket Range	72
Cedar Range	66
House Range	64
Schell Creek Range	57
Clover Mountains	53
Red Hills	46
Mountain Home Range	30
Rainbow Canyon	24
Drum Mountains	19
North Hills	13
Bull Valley Mountains	11
Iron Mountain	8
Bald Ridge	8
Shauntie Hills	6
Tunnel Spring Mountains	3
Canyon Mountains	3
Delmar Mountains	2
Chief Range	2

Table 11. Hectares of Frisco buckwheat suitable habitat predicted by all five models within mountainous localities within the modeling processing area.

MESS analysis results indicated model concordance areas where extrapolation is most predictive based on environmental similarity with Frisco buckwheat presence locations. These areas include the mountainous areas shown on Figure 11 with the number of hectares given in Table 12. Overlay analysis of MESS results for all predictors indicated areas where one or more environmental variables were outside the range of the known presence locations. Figure 12 shows the number of predictors from all five models that are outside the environmental range for Frisco buckwheat and Figure 13 shows the predictor with the value most dissimilar to presence location values across the study area.

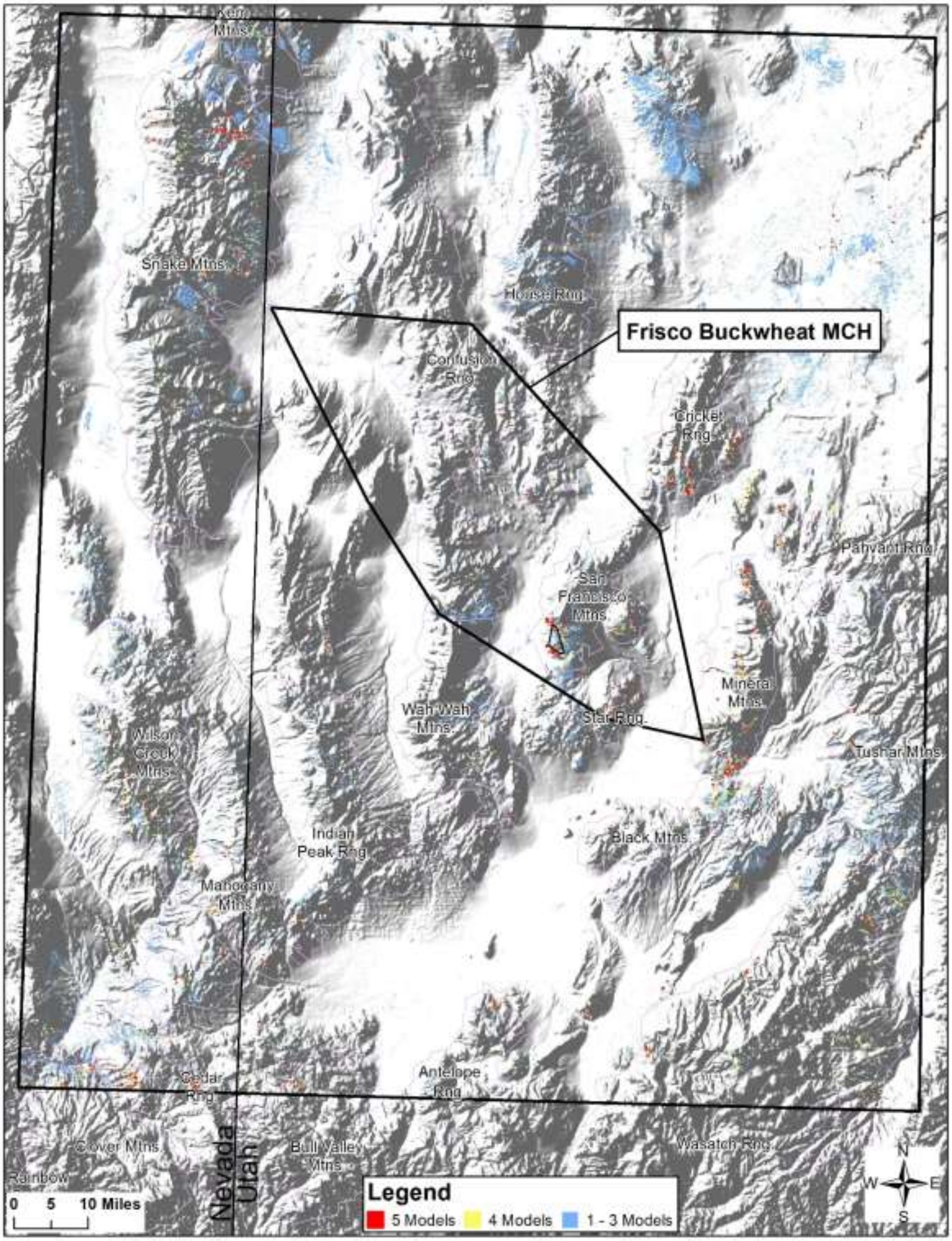

Figure 11. MESS analysis of Frisco buckwheat suitable habitat models showing concordance of areas with environmental similarity to presence locations. The large black rectangle shows the model processing area, while the small polygon within the Frisco buckwheat Minimum Convex Hull (MCH) shows the extent of surveyed presence locations.

Locality	Hectares Predicted by all 5 Models
Mineral Mountains	22
Snake Mountains	21
San Francisco Mountains	20
Cricket Range	9
Clover Mountains	8
Cedar Range	8
Black Mountains	6
Wasatch Range	6
Wilson Creek Mountains	4
Pahvant Range	3
Mahogany Mountains	3
Star Range	3
Tushar Mountains	3
Antelope Range	2
Bull Valley Mountains	2
Confusion Range	1
House Range	1
Rainbow Canyon	1
Wah Wah Mountains	1
Kern Mountains	1
Indian Peak Range	1

Table 12. Hectares of Frisco buckwheat suitable habitat predicted by all five models within mountainous localities environmentally similar to presence locations.

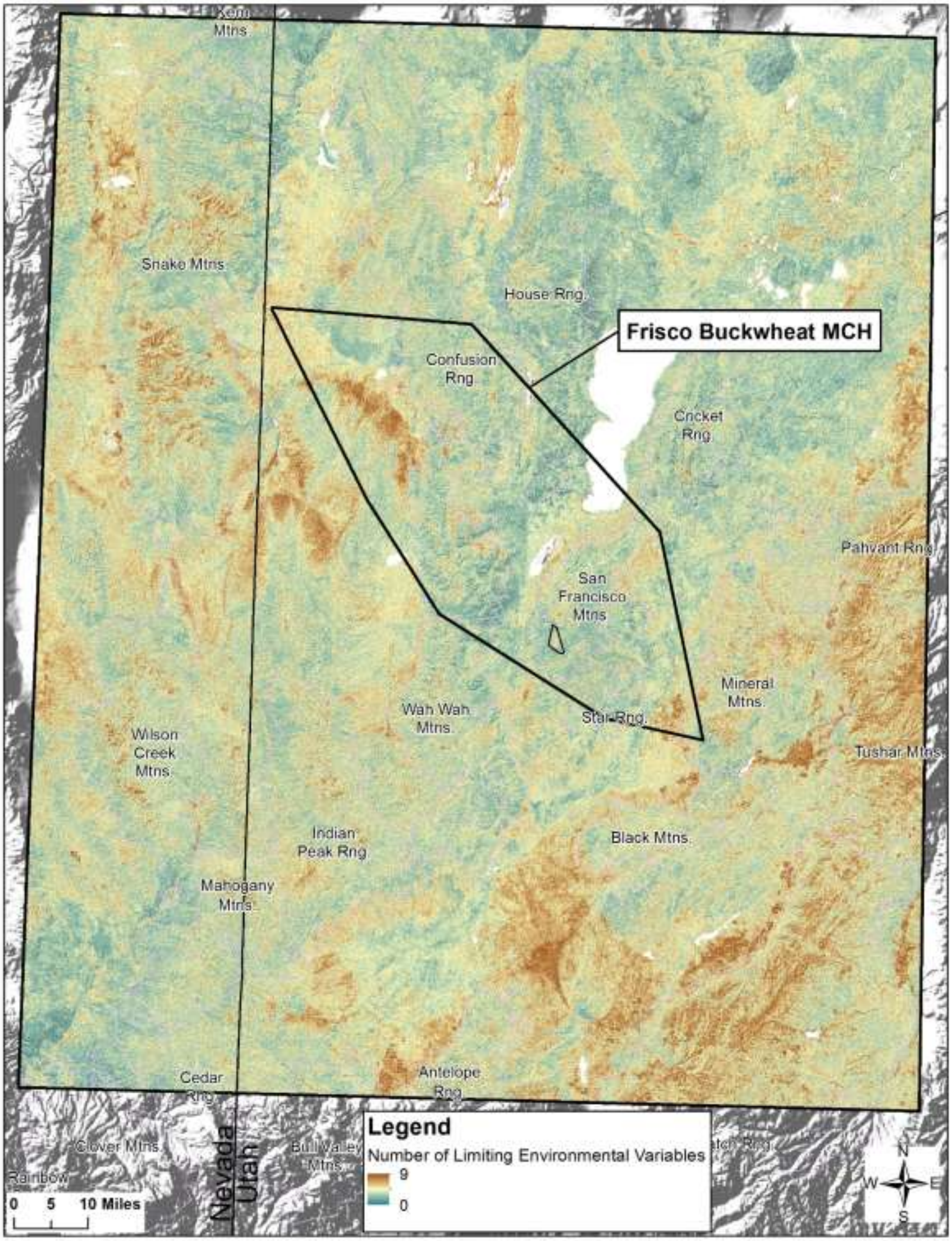

Figure 12. Number of environmental predictors outside the environmental range of Frisco buckwheat presence locations. The large black rectangle shows the model processing area, while the small polygon within the Frisco buckwheat Minimum Convex Hull (MCH) shows the extent of surveyed presence locations.

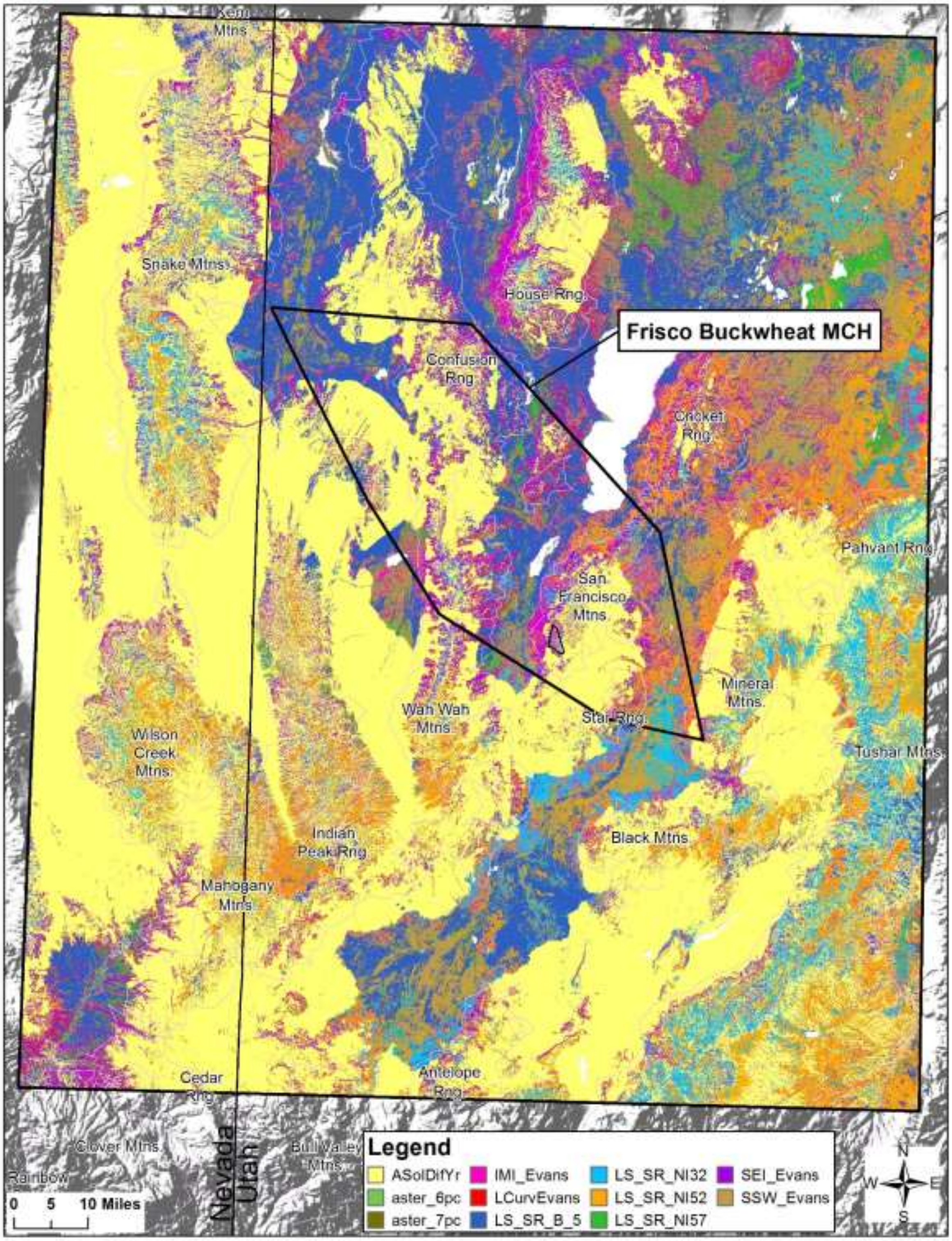

Figure 13. Environmental predictor with the most dissimilar value compared to Frisco buckwheat presence locations. The large black rectangle shows the model processing area, while the small polygon within the Frisco buckwheat Minimum Convex Hull (MCH) shows the extent of surveyed presence locations.

ii. Ostler's Peppergrass

Within the model processing area, 204,485 hectares of Ostler's peppergrass suitable habitat were predicted by all five models; 250,026 hectares were predicted by four models; and 544,975 hectares were predicted by one, two, or three models. Hectares were calculated by summing the number of cells predicted and multiplying this number by the number of hectares per 900-m^2 cell. It is important to note that this value is an extrapolation, and that the model is not predicting that plants will occur across all of the area in each predicted cell, but instead predicts that the cell will be occupied.

Within the San Francisco Mountains type locality, 3,412 hectares of suitable habitat were predicted with concordance of all five models. Figure 14 shows this area, as well as additional mountainous localities predicted to have suitable habitat by all five models. Table 13 summarizes the hectares of suitable habitat found in each mountainous area.

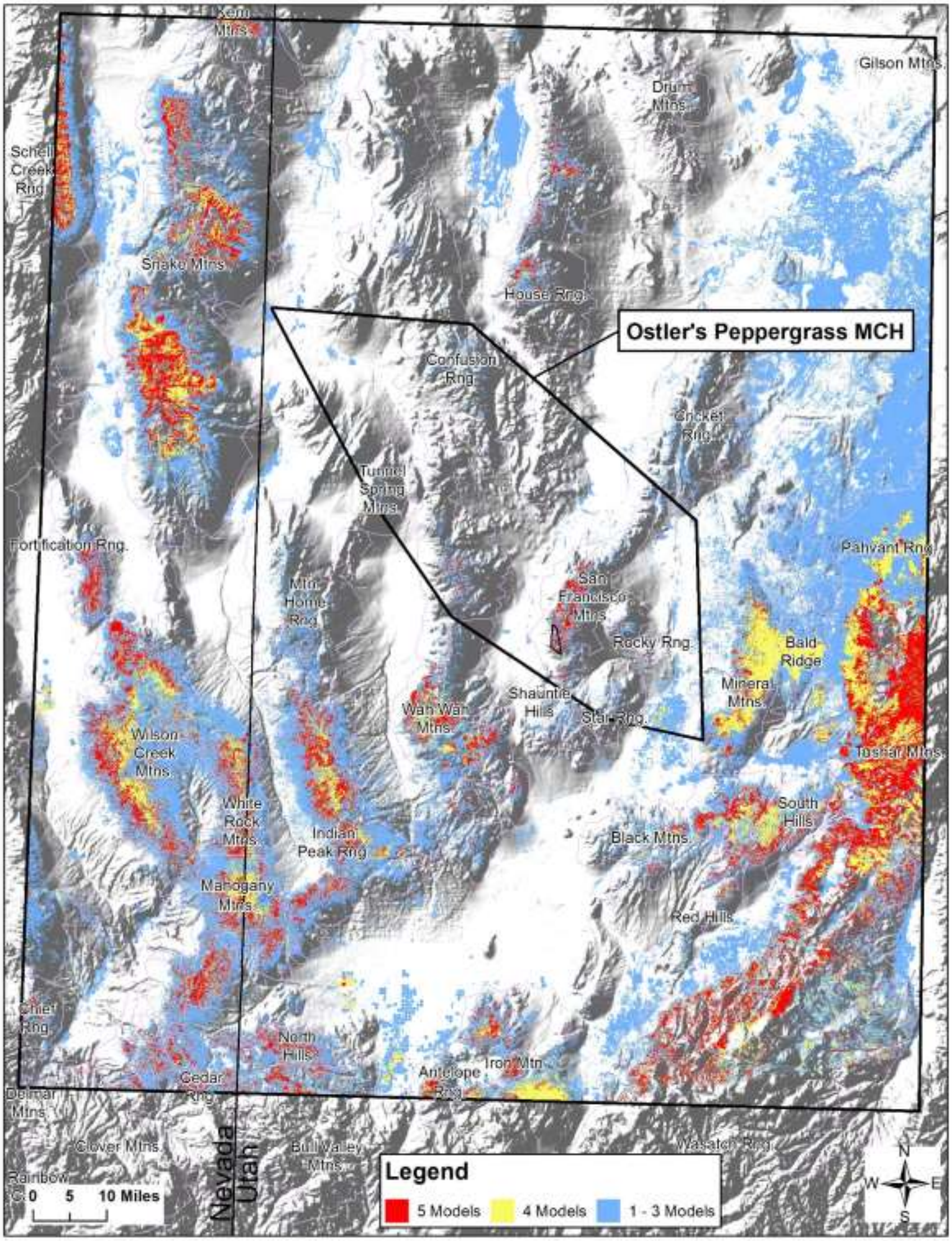

Figure 14. Ostler's peppergrass suitable habitat model concordance for five models. The large black rectangle shows the model processing area, while the small polygon within the Ostler's peppergrass Minimum Convex Hull (MCH) shows the extent of surveyed presence locations.

Locality	Hectares Predicted by all 5 Models
Tushar Mountains	39,611
Wasatch Range	39,267
Snake Mountains	27,617
Wilson Creek Mountains	16,085
Indian Peak Range	13,086
Mahogany Mountains	11,214
Wah Wah Mountains	6,278
Schell Creek Range	6,182
White Rock Mountains	6,170
Black Mountains	4,604
Mineral Mountains	3,739
San Francisco Mountains	3,412
South Hills	3,367
Fortification Range	3,190
Antelope Range	2,912
House Range	2,837
North Hills	2,509
Cedar Range	2,196
Pahvant Range	1,933
Kern Mountains	1,273
Bull Valley Mountains	1,129
Confusion Range	1,016
Iron Mountain	807
Red Hills	709
Clover Mountains	620
Mountain Home Range	604
Chief Range	532
Bald Ridge	466
Drum Mountains	250
Rainbow Canyon	225
Star Range	171
Shauntie Hills	95
Tunnel Spring Mountains	24
Delmar Mountains	20
Cricket Range	11
Burbank Hills	3

Table 13. Hectares of Ostler's peppergrass suitable habitat predicted by all five models within mountainous localities within the modeling processing area.

MESS analysis results indicated model concordance areas where extrapolation is most predictive based on environmental similarity with Ostler's peppergrass presence locations. These areas include the mountainous areas shown on Figure 15 with the number of hectares given in Table 14. Overlay analysis of MESS results for all predictors indicated areas where one or more environmental variables were outside the range of the known presence locations. Figure 16 shows the number of predictors from all five models outside the environmental range for Ostler's peppergrass within the modeling area and Figure 17 shows the predictor with the value most dissimilar to presence location values across the study area.

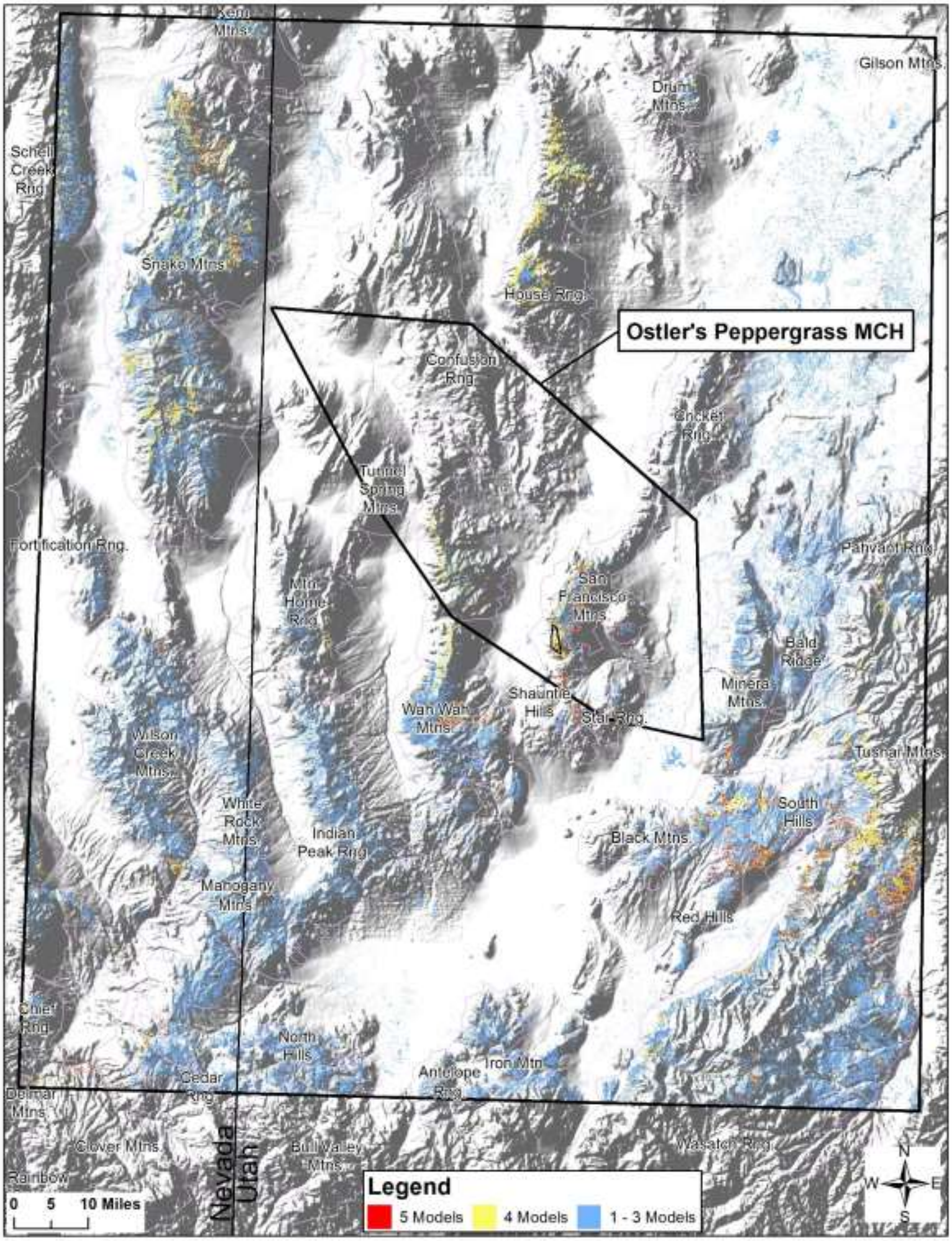

Figure 15. MESS analysis of Ostler's peppergrass suitable habitat models showing concordance of areas with environmental similarity to presence locations. The large black rectangle shows the model processing area, while the small polygon within the Ostler's peppergrass Minimum Convex Hull (MCH) shows the extent of surveyed presence locations.

Locality	Hectares Predicted by all 5 Models
Wasatch Range	948
Snake Mountains	826
San Francisco Mountains	517
South Hills	311
Black Mountains	299
Tushar Mountains	267
Wah Wah Mountains	250
Schell Creek Range	188
Mineral Mountains	185
House Range	142
Red Hills	63
Star Range	51
Rainbow Canyon	50
Confusion Range	44
Wilson Creek Mountains	41
Antelope Range	40
Kern Mountains	36
Indian Peak Range	29
Chief Range	28
Shauntie Hills	23
Cedar Range	22
White Rock Mountains	21
Mountain Home Range	20
Iron Mountain	17
Pahvant Range	16
Drum Mountains	14
Clover Mountains	12
Bald Ridge	12
Mahogany Mountains	9
Fortification Range	6
Bull Valley Mountains	6
Delmar Mountains	5
Tunnel Spring Mountains	3
Cricket Range	3
North Hills	1

Table 14. Hectares of Ostler's peppergrass suitable habitat predicted by all five models within mountainous localities environmentally similar to presence locations.

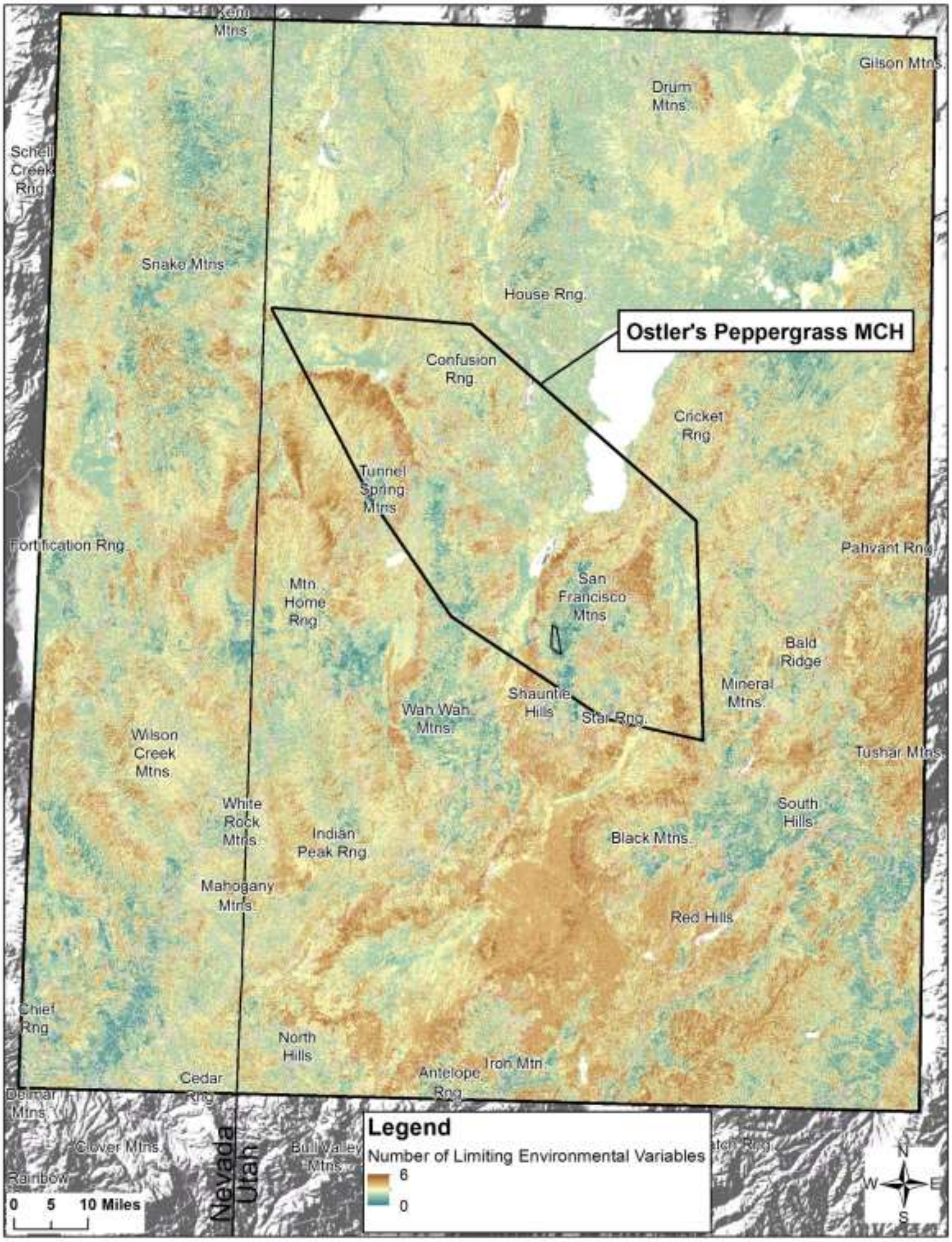

Figure 16. Number of environmental predictors outside the environmental range of Ostler's peppergrass presence locations. The large black rectangle shows the model processing area, while the small polygon within the Ostler's peppergrass Minimum Convex Hull (MCH) shows the extent of surveyed presence locations.

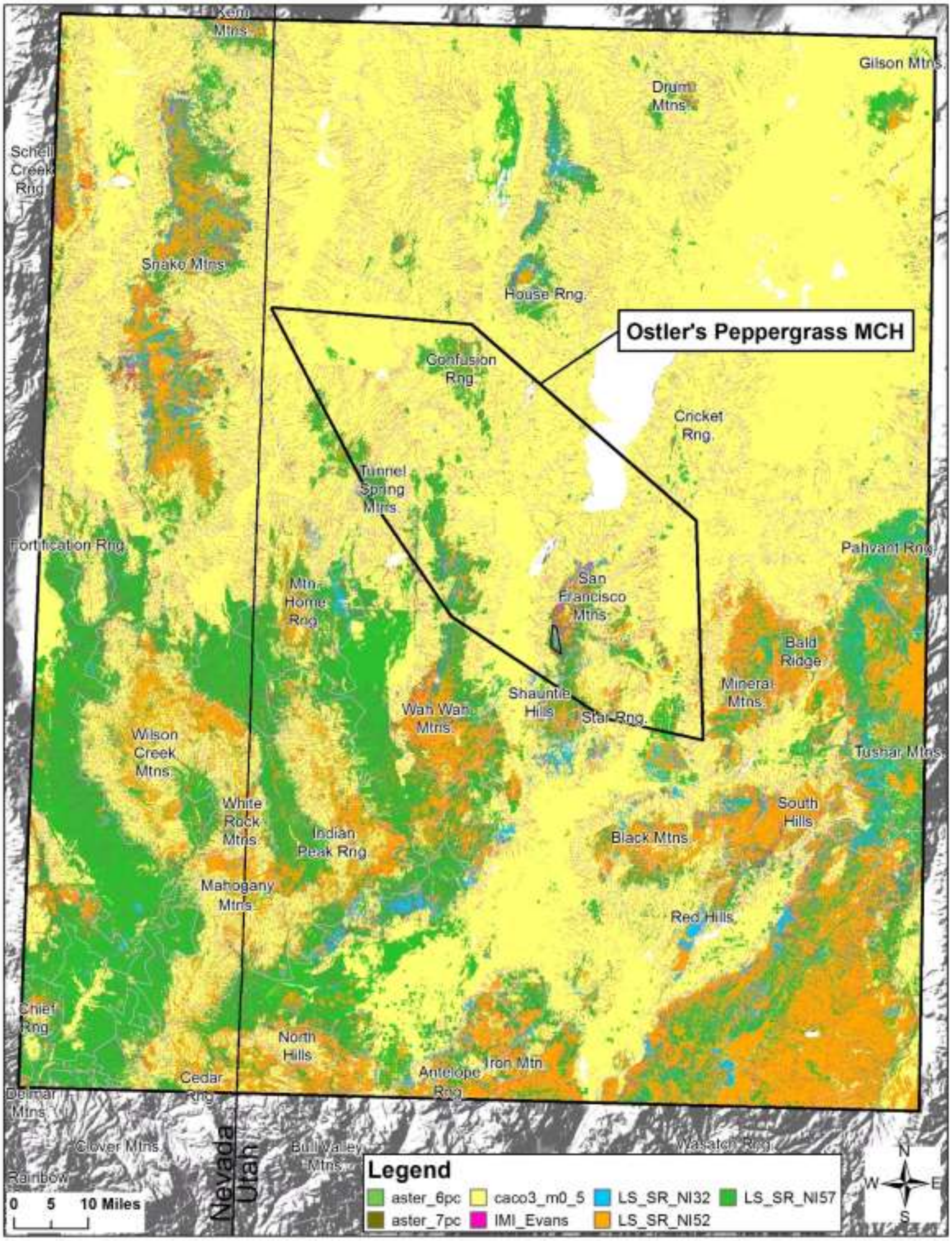

Figure 17. Environmental predictor with the most dissimilar value compared to Ostler's peppergrass presence locations. The large black rectangle shows the model processing area, while the small polygon within the Ostler's peppergrass Minimum Convex Hull (MCH) shows the extent of surveyed presence locations.

iii. Frisco Clover

Within the model processing area, 66,401 hectares of Frisco clover suitable habitat were predicted by all five models; 85,453 hectares were predicted by four models; and 640,860 hectares were predicted by one, two, or three models. Hectares were calculated by summing the number of cells predicted and multiplying this number by the number of hectares per 900-m^2 cell. It is important to note that this value is an extrapolation, and that the model is not predicting that plants will occur across all of the area in each predicted cell, but instead predicts that the cell will be occupied.

Within the San Francisco Mountains type locality, 922 hectares of suitable habitat were predicted with concordance of all five models. Figure 18 shows this area, as well as additional mountainous localities predicted to have suitable habitat by all five models. Table 15 summarizes the hectares of suitable habitat found in each mountainous area.

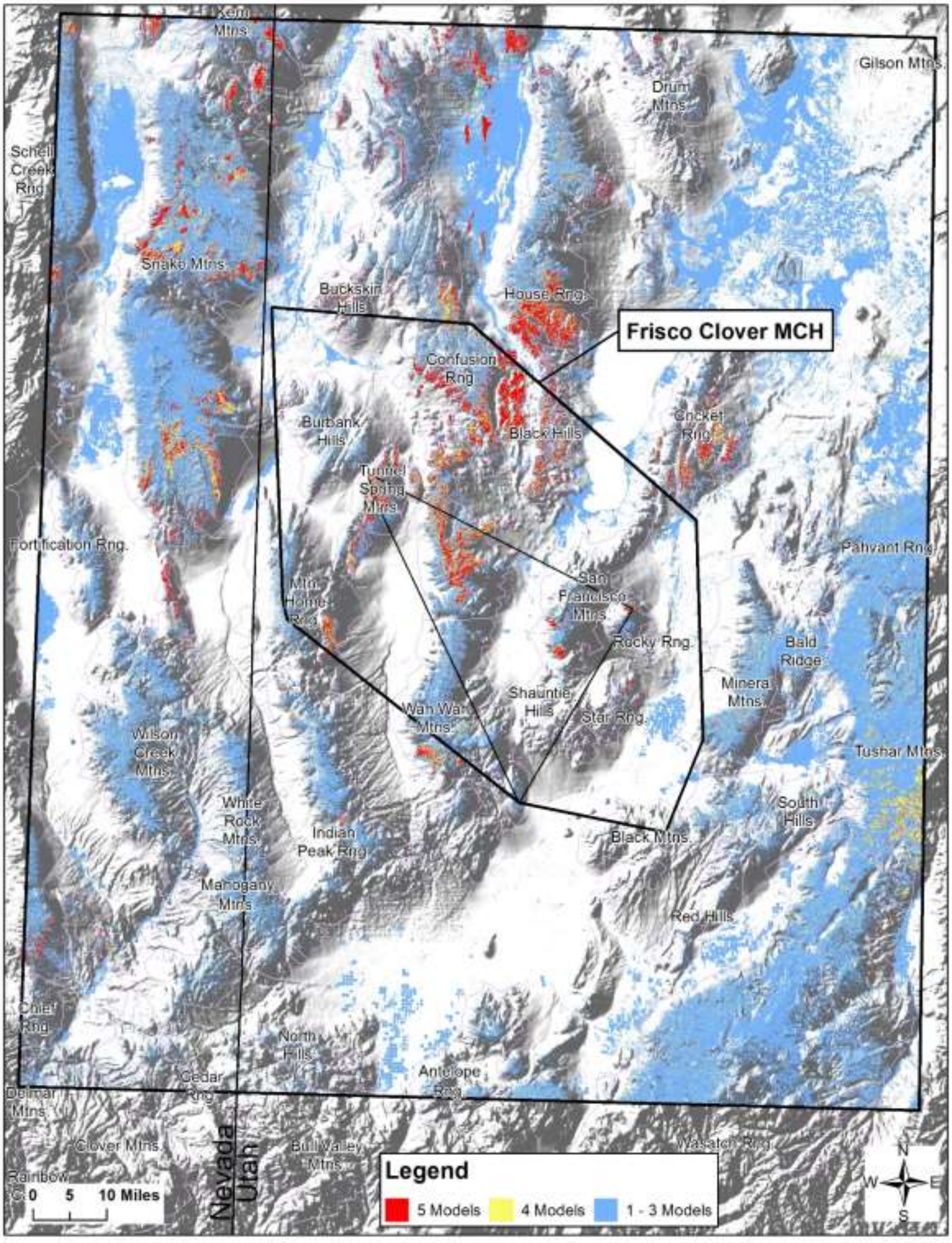

Figure 18. Frisco clover suitable habitat model concordance for five models. The polygon within the MCH shows the extent of surveyed presence locations. The large black rectangle shows the model processing area, while the small polygon within the Frisco clover Minimum Convex Hull (MCH) shows the extent of surveyed presence locations.

Locality	Hectares Predicted by all 5 Models
Confusion Range	19,745
Snake Mountains	13,781
House Range	9,661
Cricket Range	3,639
Tunnel Spring Mountains	2,215
Schell Creek Range	2,135
Black Hills	2,034
Kern Mountains	1,811
Mountain Home Range	1,672
Wilson Creek Mountains	1,334
Tushar Mountains	1,263
Wah Wah Mountains	1,150
Buckskin Hills	949
San Francisco Mountains	922
Wasatch Range	803
Mineral Mountains	761
Indian Peak Range	412
Burbank Hills	400
Star Range	381
Pahvant Range	378
Drum Mountains	245
Fortification Range	190
Black Mountains	113
Mahogany Mountains	110
Bald Ridge	95
White Rock Mountains	60
Chief Range	23
Shauntie Hills	22
Antelope Range	16
South Hills	15
Rainbow Canyon	10
Clover Mountains	9
Cedar Range	9
North Hills	3
Rocky Range	3
Red Hills	2
Delmar Mountains	2
Bull Valley Mountains	1

Table 15. Hectares of Frisco clover suitable habitat predicted by all five models within mountainous localities within the modeling processing area.

MESS analysis results indicated model concordance areas where extrapolation is most predictive based on environmental similarity with Frisco clover presence locations. These areas include the mountainous areas shown on Figure 19 with the number of hectares given in Table 16. Overlay analysis of MESS results for all predictors indicated areas where one or more environmental variables were outside the range of the known presence locations. Figure 20 shows the number of predictors from all five models outside the environmental range for Frisco clover within the modeling area and Figure 21 shows the predictor with the value most dissimilar to presence location values across the study area.

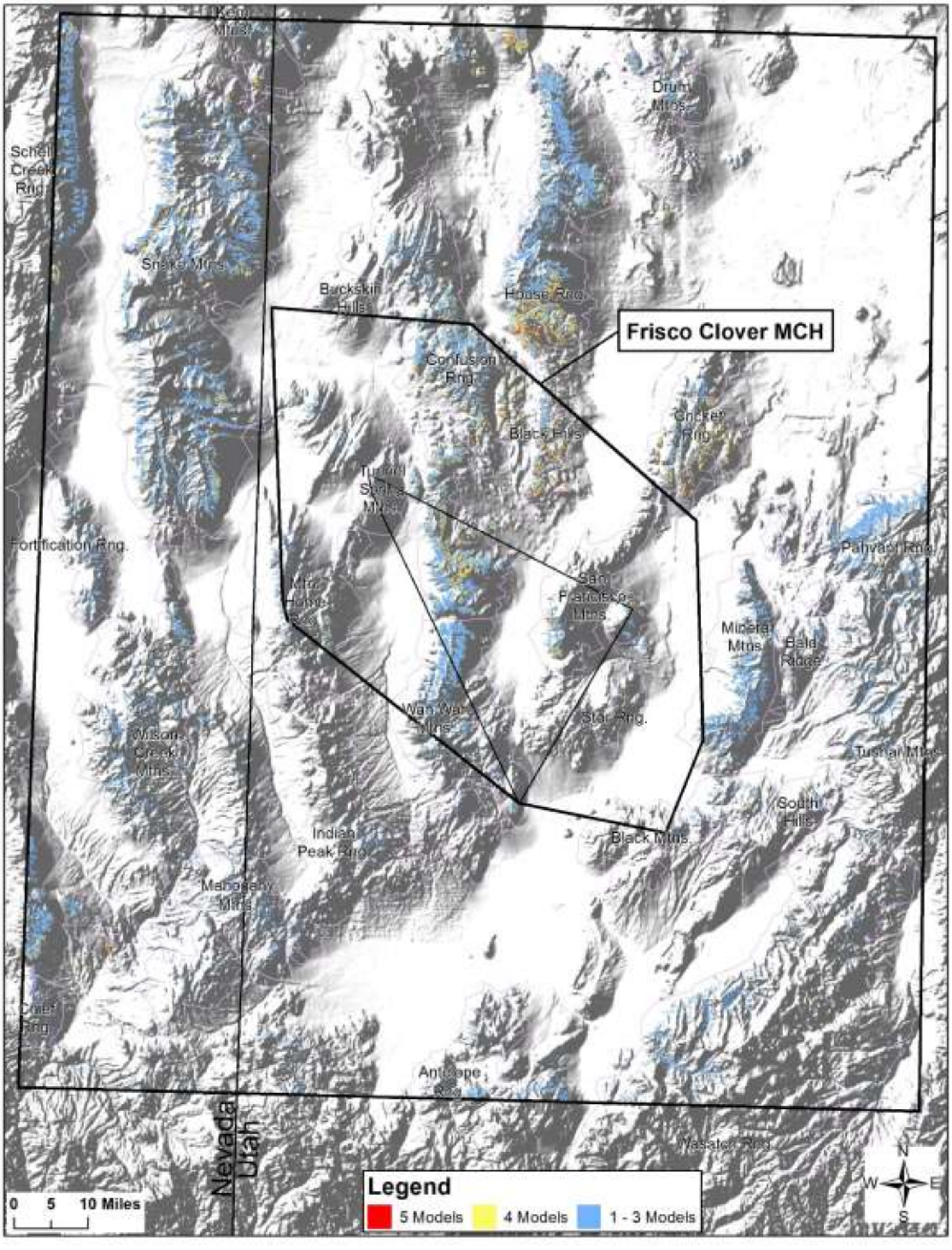

Figure 19. MESS analysis of Frisco clover suitable habitat models showing concordance of areas with environmental similarity to presence locations. The large black rectangle shows the model processing area, while the small polygon within the Frisco clover Minimum Convex Hull (MCH) shows the extent of surveyed presence locations.

Locality	Hectares Predicted by all 5 Models
House Range	719
Confusion Range	600
Snake Mountains	515
Cricket Range	232
Black Hills	140
Schell Creek Range	124
San Francisco Mountains	49
Wah Wah Mountains	32
Kern Mountains	29
Mineral Mountains	27
Tunnel Spring Mountains	23
Pahvant Range	20
Wilson Creek Mountains	19
Wasatch Range	16
Mountain Home Range	15
Drum Mountains	14
Star Range	13
Tushar Mountains	5
Fortification Range	3
Mahogany Mountains	3
Buckskin Hills	3
Black Mountains	2
Chief Range	2
Indian Peak Range	2
South Hills	1
Antelope Range	1
Bald Ridge	1

Table 16. Hectares of Frisco clover suitable habitat predicted by all five models within mountainous localities environmentally similar to presence locations.

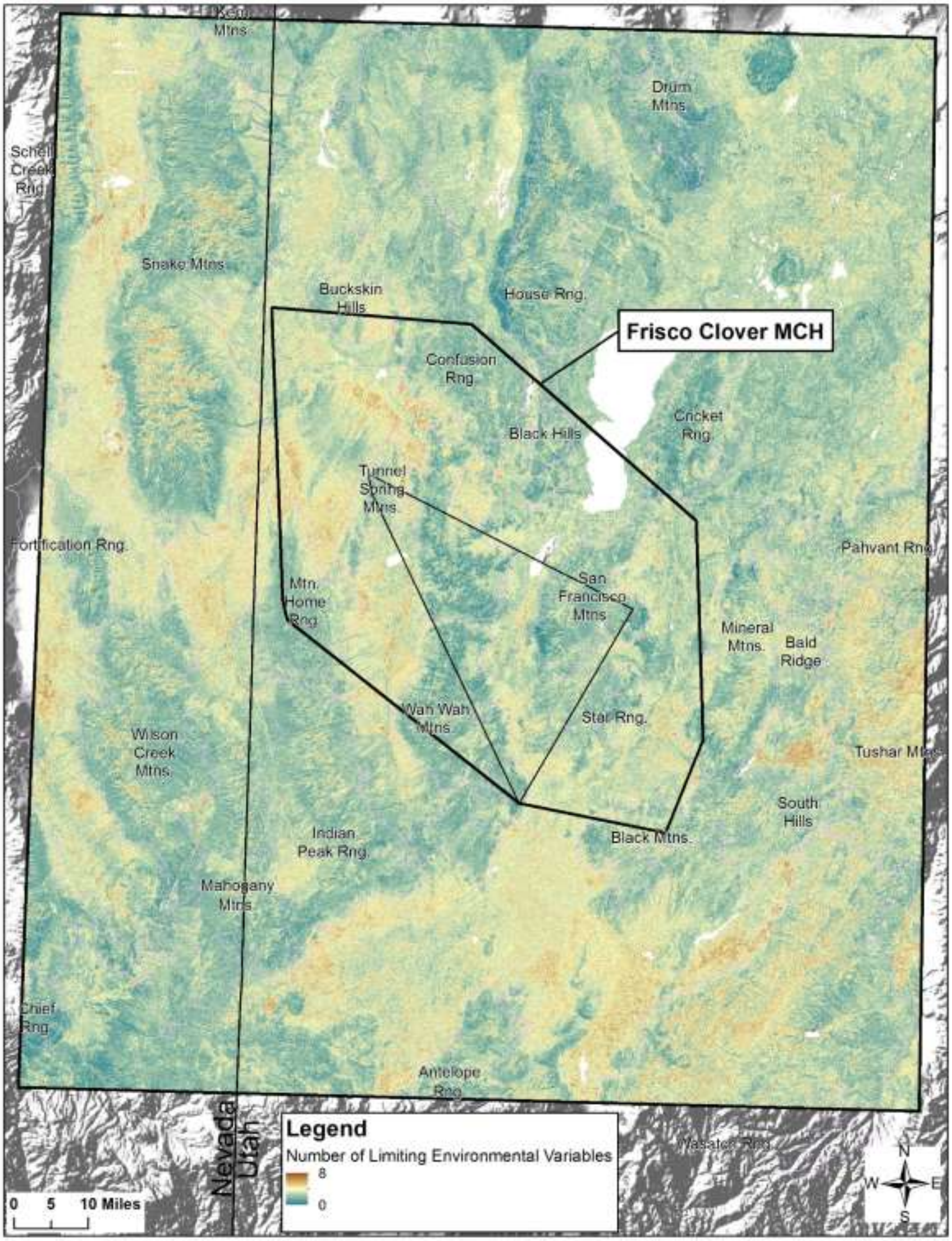

Figure 20. Number of environmental predictors outside the environmental range of Frisco clover presence locations. The large black rectangle shows the model processing area, while the small polygon within the Frisco clover Minimum Convex Hull (MCH) shows the extent of surveyed presence locations.

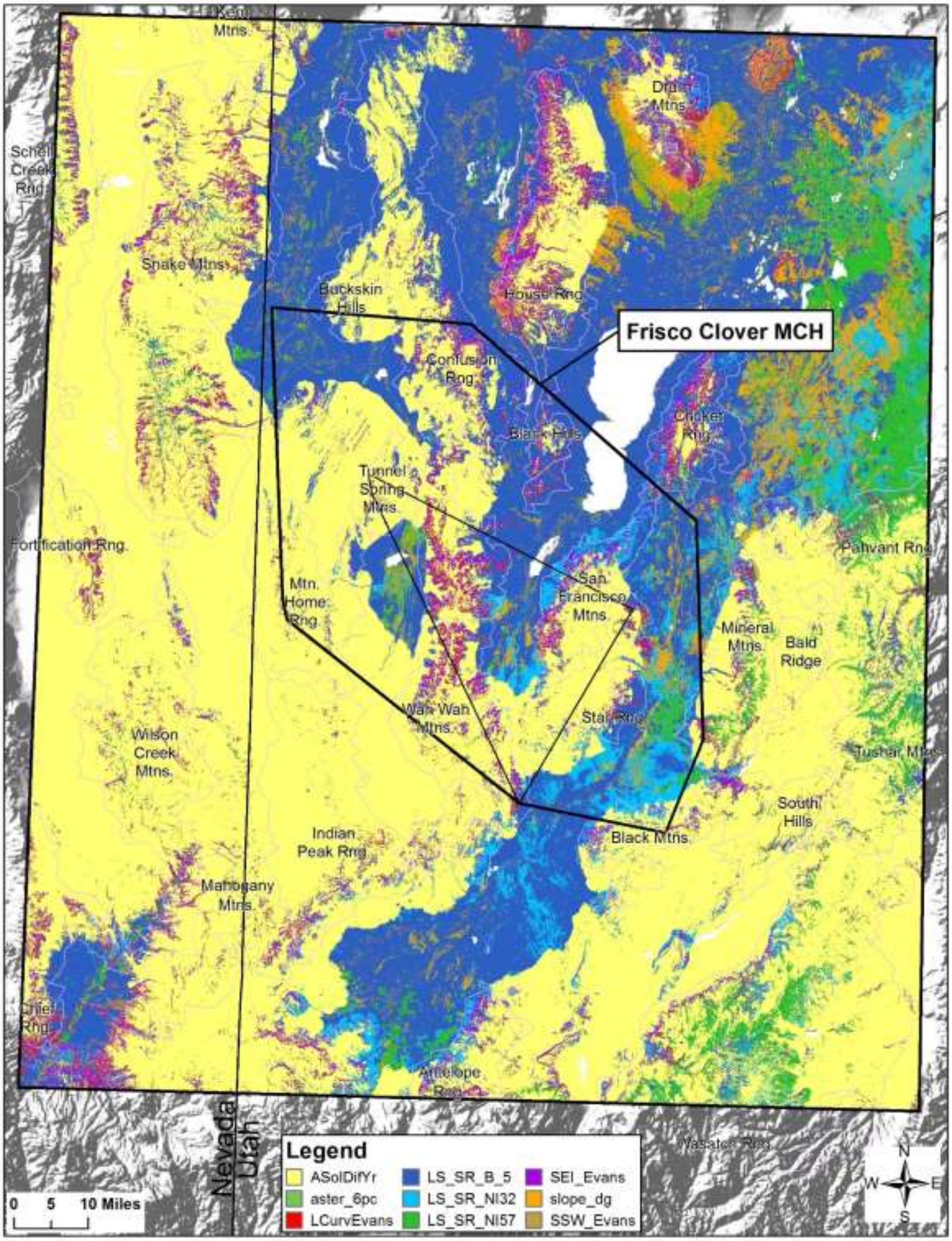

Figure 21. Environmental predictor with the most dissimilar value compared to Frisco clover presence locations. The large black rectangle shows the model processing area, while the small polygon within the Frisco clover Minimum Convex Hull (MCH) shows the extent of surveyed presence locations.

iv. Frisco endemic species together

Within the model processing area, 18,909 hectares of suitable habitat for all three species were predicted by all five models; 45,889 hectares were predicted by four models; and 509,940 hectares were predicted by one, two, or three models. Hectares were calculated by summing the number of cells predicted and multiplying this number by the number of hectares per 900-m^2 cell. It is important to note that this value is an extrapolation, and that the model is not predicting that plants will occur across all of the area in each predicted cell, but instead predicts that the cell will be occupied.

Within the San Francisco Mountains type locality, 649 hectares of suitable habitat were predicted with concordance of all five models. Figure 22 shows this area, as well as additional mountainous localities predicted to have suitable habitat by all five models. Table 17 summarizes the hectares of suitable habitat found in each mountainous area.

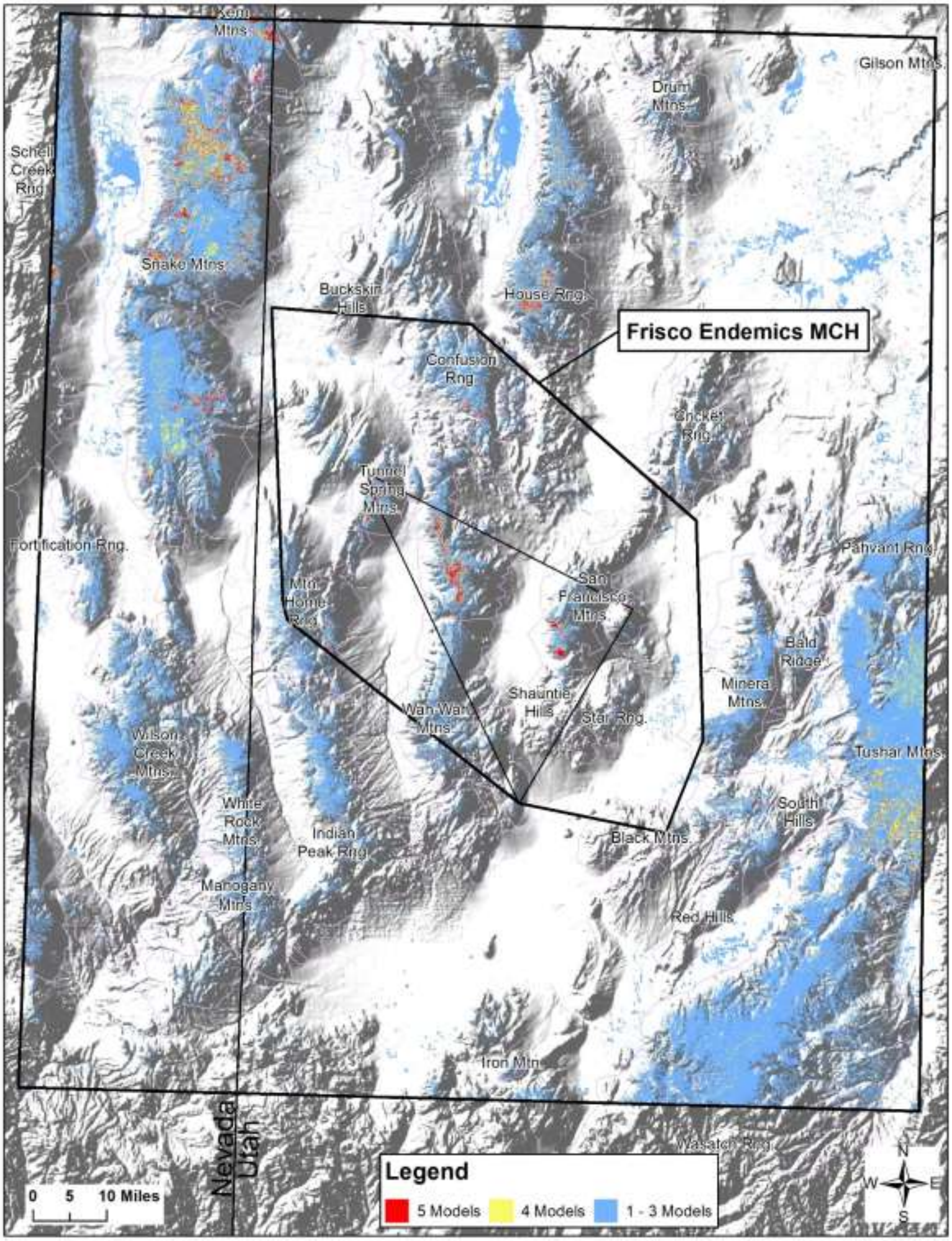

Figure 22. Frisco endemic species suitable habitat model concordance for five models. The large black rectangle shows the model processing area, while the small polygon within the Frisco endemics Minimum Convex Hull (MCH) shows the extent of surveyed presence locations.

Locality	Hectares Predicted by all 5 Models
Snake Mountains	7,484
Confusion Range	2,624
House Range	1,909
Tushar Mountains	1,262
Kern Mountains	930
Wasatch Range	653
San Francisco Mountains	649
Schell Creek Range	626
Tunnel Spring Mountains	573
Wilson Creek Mountains	367
Mountain Home Range	320
Wah Wah Mountains	277
Indian Peak Range	271
Mineral Mountains	245
Black Mountains	244
Fortification Range	110
Cricket Range	88
White Rock Mountains	66
Star Range	55
Mahogany Mountains	48
Buckskin Hills	42
Pahvant Range	36
South Hills	15
Iron Mountain	5
Drum Mountains	4
Bald Ridge	1
Shauntie Hills	1
Red Hills	1

Table 17. Hectares of Frisco endemic species suitable habitat predicted by all five models within mountainous localities within the modeling processing area.

v. Niche Similarity Comparison by Species

Figures 23 and 24 show bean plots comparing environmental predictors that were found to be important for all three species when models were fit separately. These plots show the distribution and mean of values found at both presence and pseudo absence locations for all three species. These plots can suggest differences in environmental conditions found at presence locations from those found where the species does not exist.

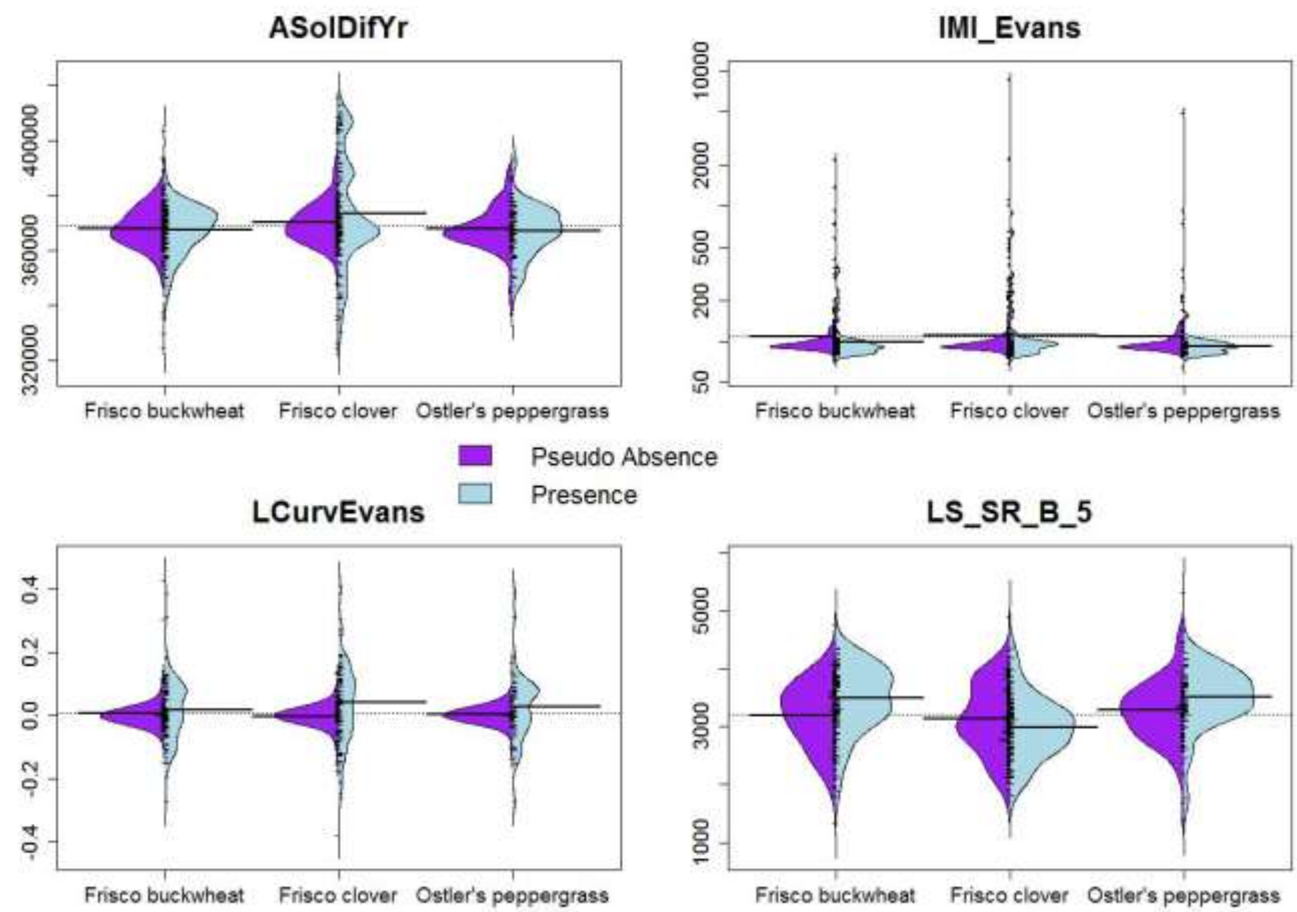

Figure 23. Bean plots for Area Solar Radiation Whole Year Difuse (ASolDifYr), Integrated Moisture Index (IMI_Evans), Landform Curvature (LCurvEvans), and Landsat surface reflectance band 5 (LS_SR_B_5). The shape of the beanplots show the density of values, and the short horizontal lines represent each data point, with longer lines given when there are duplicate values. The mean of each data set is represented by a longer black line on each side of the bean, and the mean of all beans is represented by the dashed line.

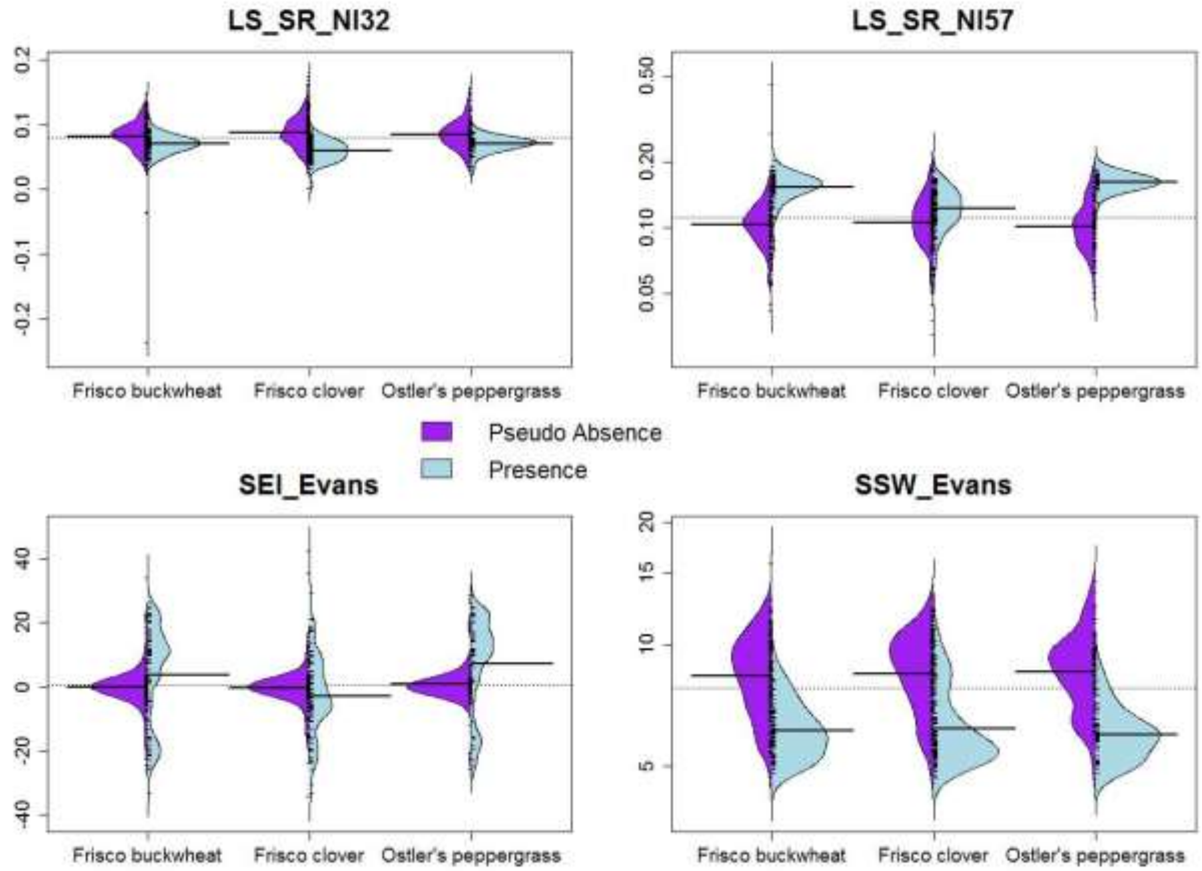

Figure 24. Bean plots for 3/2 normalized surface reflectance (LS_SR_NI52), 5/7 normalized surface reflectance (LS_SR_NI57), Site Exposure Index (SEI_Evans), and Steady State Wetness Index (SSW_Evans). The shape of the beanplots show the density of values, and the short horizontal lines represent each data point, with longer lines given when there are duplicate values. The mean of each data set is represented by a longer black line on each side of the bean, and the mean of all beans is represented by the dashed line.

4. **Discussion and Recommendations**

4a. Population and Soil Survey Locations and Future Modeling

The results of ensemble modeling highlighted localities where one through five species distribution models predict suitable habitat for three plant species endemic to the San Francisco Mountains in Utah. Model results with concordance for all five models predicted 8,802 hectares of Frisco buckwheat suitable habitat in 37 mountainous localities; 204,485 hectares of Ostler's peppergrass suitable habitat in 36 localities; 66,401 hectares of Frisco clover suitable habitat in 38 localities; and 18,909 hectares of suitable habitat for all three species in 28 localities. Hectares were calculated by summing the number of cells predicted and multiplying this number by the number of hectares per 900-m^2 cell. It is important to note that this value is an extrapolation, and that the model is not predicting that plants will occur across all of the area in each predicted cell, but instead predicts that the cell will be occupied. Because the species vary in the number of presence locations available, the modeling results differ in how well they are able to predict suitable habitat, with species with lower numbers of observations having less robust predictions. For example, because Ostler's peppergrass currently has only 39 presence locations (after generalizing to 30-m pixels), fewer numbers of environmental predictors were able to be used to fit models. This results in the over-prediction of potential habitat for Ostler's peppergrass of more than three times the hectares predicted for Frisco clover, and more than 20 times that predicted for Frisco buckwheat. This is a known limitation of SDMs, and reinforces the need for additional well designed surveys. All currently know populations of Ostler's peppergrass co-occur with Frisco buckwheat, so future modeling could combine the two species until there are high enough numbers of Ostler's peppergrass to model it alone.

I recommend that field surveys of localities with concordance of five models be made to locate new plant populations, field validate, and improve these models. Survey locations should be selected within these areas using a random study design. Surveys should be made using transects that travel the cross section of habitat modeled by not only five models, but also the adjacent areas identified by one to four models. These same transects could be used to conduct soil sampling and conduct UAV studies, which may contribute to additional environmental predictor data and a better understanding of species resource needs. As mentioned, species bounding boxes delineated based on expert opinion will be provided in the near future to help prioritize future sampling locations. Surveys could be prioritized within the bounding box area designated; however, in order to strengthen the models and improve understanding of the species, areas outside this box, but still highlighted by these models, should be considered in future survey design.

4b. Potential Locations for Seed/Plant Introduction and Proactive Conservation

A more conservative approach to suggest locations for species introduction and proactive conservation was considered appropriate due to the costs involved in these efforts. The multivariate environmental similarity surfaces technique was chosen to narrow model predictions to those areas most likely to be suitable for each species. MESS models show areas most environmentally similar to presence locations for the species, and removes areas where at least one predictor variable is outside this range. As expected this approach reduces the predicted areas considerably, and MESS concordance for all five models predicted only 131 hectares of Frisco buckwheat suitable habitat in 21 mountainous localities; 4,509 hectares of Ostler's peppergrass suitable habitat in 35 localities; and 2,614 hectares of Frisco clover suitable habitat in 27 localities. MESS analysis was not conducted for all Frisco endemic species together. The same caveat regarding the interpretation of hectare predictions applies here as well.

4c. Important Environmental Variables

The environmental variables chosen for model fitting for each species relied on the predictor not being collinear with other variables, and being a good predictor during test model runs. Additionally, because we had fairly limited presence data for each species, the number of predictors were limited to prevent model over-fitting. From the predictors used for modeling, four were selected for model fitting by all three species. These were:

- LS_SR_NI32: the 3/2 normalized surface reflectance band ratio, indicating carbonates (Baker et al. 2016), included in 7 models;
- aster_6pc: the satellite derived mineral carbonate-propylitic percent cover data (Rockwell et al. 2017), included in 13 models;
- aster_7pc: the satellite derived dolomite percent cover data (Rockwell et al. 2017), included in 6 models; and
- LS_SR_NI57: the 5/7 normalized surface reflectance band ratio, indicating Gypsum (Ahrens, et al., 2008), included in 11 models.

All four of these predictors have soil calcium properties, with carbonate being the more general term, of which the most common minerals are calcite or calcium carbonate. Dolomite is an anhydrous carbonate of the trigonal form (calcium carbonate and magnesium; $CaMg(CO3)2$) and gypsum is an evaporate sulfite mineral ($CaSO4{\cdot}2H2O$).

The 3/2 band ratio indicating carbonates was found to have a positive relationship with Frisco buckwheat presence, while having a negative relationship with Ostler's peppergrass and Frisco clover presence. However, satellite derived carbonate-propylitic data indicated a positive relationship with both Frisco buckwheat and Frisco clover presence. The beanplot for 3/2 band ratio data (carbonates; LS_SR_NI32) shows lower mean values in the presence data versus higher mean values in pseudo absence data for all three species, suggesting a negative relationship to presence. Beanplots were not able to be generated from carbonate percent cover data due to the sample being too sparse. The 5/7 normalized surface reflectance band ratio, indicating Gypsum, had a positive relationship with presence by all three species, and the beanplots show a higher mean for presence data than for pseudo absence data for all three species, supporting a positive relationship. The satellite derived dolomite layer was not modeled by GLM or GAM, and therefore no relationship direction is indicated. These results suggest that calcium soil properties, including carbonate, gypsum, and dolomite, are important to these three species, but more study will need to be done to determine their relationship and function.

Nine predictors were selected for modeling by two species. Of these, the following interesting observations were noted.

- SSW_Evans: Steady state wetness index indicating soil moisture was used in both Frisco buckwheat and Frisco clover modeling and beanplots suggest that lower soil moisture is associated with species presence.
- SEI_Evans: Site exposure index indicating a range of cool to warm values was used in both Frisco buckwheat and Frisco clover modeling, while beanplots suggest warmer temperatures are associated with Frisco buckwheat presence, and lower temperatures are associated with Frisco clover presence.
- LS_SR_B_5: Shortwave Infrared regression analysis suggest a positive relationship for both Frisco buckwheat and Frisco clover for this band, while beanplots suggest this band has a positive relationship with presence for Frisco buckwheat and Ostler’s peppergrass, and a negative relationship for Frisco clover.
- G_EraI7pc: Geologic Era, Ordovician regression analysis suggests a positive relationship with both Frisco buckwheat and Frisco clover presence.
- IMI_Evans: Integrated moisture index estimate of soil moisture was used in both Frisco buckwheat and Ostler’s peppergrass modeling and beanplots indicate the lower soil moisture is associated with species presence, supporting the SSW_Evans measure for Frisco buckwheat.

The Most Dissimilar Value (MoD) for a species is the environmental value with the smallest value of similarity from the set of presence values. I found that for both Frisco buckwheat and Frisco clover the area of diffuse solar radiation measured over the year was the most dissimilar with the largest hectares across the modeled area. While for Ostler’s peppergrass, the MoD with the largest hectares was percent Calcium carbonate in soil, 0-5 cm (caco3_m0_5).

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Appendix I.

Environmental Variable	Description	Geoprocessing and Reference	Environmental Feature(s) Represented
ASolDifYr	Area Solar Radiation Whole Year Difuse	Processed 30-m elevation using ESRI ArcGIS Area Solar Radiation function using methods from from the hemispherical viewshed algorithm developed by Rich et al. (Rich 1990, Rich et al. 1994) and further developed by Fu and Rich (2000, 2002).	Soil moisture, depth, aspect effects (Baker et al., 2016)
ASolDirYr	Area Solar Radiation Whole Year Direct	Processed 30-m elevation using ESRI ArcGIS Area Solar Radiation function using methods from from the hemispherical viewshed algorithm developed by Rich et al. (Rich 1990, Rich et al. 1994) and further developed by Fu and Rich (2000, 2002).	Soil moisture, depth, aspect effects (Baker et al., 2016)
ASolDurYr	Area Solar Radiation Whole Year Duration	Processed 30-m elevation using ESRI ArcGIS Area Solar Radiation function using methods from from the hemispherical viewshed algorithm developed by Rich et al. (Rich 1990, Rich et al. 1994) and further developed by Fu and Rich (2000, 2002).	Soil moisture, depth, aspect effects (Baker et al., 2016)
ASolGlobYr	Area Solar Radiation Whole Year Global	Processed 30-m elevation using ESRI ArcGIS Area Solar Radiation function using methods from from the hemispherical viewshed algorithm developed by Rich et al. (Rich 1990, Rich et al. 1994) and further developed by Fu and Rich (2000, 2002).	Soil moisture, depth, aspect effects (Baker et al., 2016)
aster_6pc	Carbonate-propylitic percent cover.	From: Digital maps of hydrothermal alteration type, key mineral groups, and green vegetation of the western United States derived from automated analysis of ASTER satellite data https://www.sciencebase.gov/catalog/item/58cc1f95e4b0849ce97dce60. Geoprocessed using Focal Mean with a 3x3 window.	Soil and minerals
aster_7pc	Dolomite (may include Mg/Fe-OH phyllosilicates or epidote in igneous and metamorphic terranes) percent cover.	From: Digital maps of hydrothermal alteration type, key mineral groups, and green vegetation of the western United States derived from automated analysis of ASTER satellite data https://www.sciencebase.gov/catalog/item/58cc1f95e4b0849ce97dce60. Geoprocessed using Focal Mean with a 3x3 window.	Soil and minerals
aster_21pc	Ferrous or coarse-grained ferric iron (may include oxidized basalts, fire ash, some moist soils, and any blue/green rocks)	From: Digital maps of hydrothermal alteration type, key mineral groups, and green vegetation of the western United States derived from automated analysis of ASTER satellite data https://www.sciencebase.gov/catalog/item/58cc1f95e4b0849ce97dce60. Geoprocessed using Focal Mean with a 3x3 window.	Soil and minerals
caco3_m0_5	Percent Calcium carbonate in soil, 0-5 cm	POLARIS soil data 3 arc second properties at: http://stream.princeton.edu/POLARIS/PROPERTIES/3arcsec/ ~ 90m resolution (resampled to 30m)	Soil and minerals
Elev30m	Elevation (in cm)	NHD plus (http://www.horizon-systems.com/nhdplus/)	Temperature, soil moisture
G_EraI2pc	Geologic Era, Devonian	Geologic Era. This comes from combination of various 30 x 60 degree geologic mapping polygon files and 100k geologic files. Geoprocessed using a Focal Mean with a 3x3 window.	Geology
G_EraI7pc	Geologic Era, Ordovician	Geologic Era. This comes from combination of various 30 x 60 degree geologic mapping polygon files and 100k geologic files. Geoprocessed using a Focal Mean with a 3x3 window.	Geology

Environmental Variable	Description	Geoprocessing and Reference	Environmental Feature(s) Represented
G_EraI12pc	Geologic Era, Quaternary	Geologic Era. This comes from combination of various 30 x 60 degree geologic mapping polygon files and 100k geologic files. Geoprocessed using a Focal Mean with a 3x3 window.	Geology
G_EraI13pc	Geologic Era, Silurian	Geologic Era. This comes from combination of various 30 x 60 degree geologic mapping polygon files and 100k geologic files. Geoprocessed using a Focal Mean with a 3x3 window.	Geology
G_EraI14pc	Geologic Era, Tertiary	Geologic Era. This comes from combination of various 30 x 60 degree geologic mapping polygon files and 100k geologic files. Geoprocessed using a Focal Mean with a 3x3 window.	Geology
HLI_Evans	Heat Load Index	Heat Load Index (McCune & Keon 2002). Calculated using Geomorphometry & Gradient Metrics V. 2 Evans et al using 10 m resolution elevation data later aggregated to 30 m. A southwest facing slope should have warmer temperatures Heat load index than a southeast facing slope, even though the amount of solar radiation they receive is equivalent. The McCune and Keon (2002) method accounts for this by "folding" the aspect so that the highest values are southwest and the lowest values are northeast. Additionally, this method account for steepness of slope, which is not addressed in most other aspect rescaling equations. HLI values range from 0 (coolest) to 1 (hottest).	Temperature
IMI_Evans	Integrated Moisture Index	Integrated Moisture Index is an estimate of soil moisture in topographically heterogeneous landscapes (Iverson et al., 1997). Calculated using Geomorphometry & Gradient Metrics V. 2 Evans et al using 10 m resolution elevation data later aggregated to 30 m.	Soil Moisture
LCurvEvans	Landform Curvature	Landform Curvature (concavity/convexity) index (Bolstad's variant). Calculated using Geomorphometry & Gradient Metrics V. 2 Evans et al using 10 m resolution elevation data later aggregated to 30 m. The index is based on features that confine the view from the center of a 3x3 window. Edge correction is addressed be dividing by the radius distance to the outermost cell. The landform curvature at a cell 'X' is calculated within a 3x3 rectangular window centered on X.	Soil moisture, soil depth, soil production, water shedding.
LS_SR_B_1	Landsat surface reflectance band 1	USGS ESPA High-level products. Five tiles. June, 2011	Water vegetation, soil and mineral spectral reflection (Baker et al. 2016)
LS_SR_B_2	Landsat surface reflectance band 2	USGS ESPA High-level products. Five tiles. June, 2011	Water vegetation, soil and mineral spectral reflection (Baker et al. 2016)
LS_SR_B_3	Landsat surface reflectance band 3	USGS ESPA High-level products. Five tiles. June, 2012	Water vegetation, soil and mineral spectral reflection (Baker et al. 2016)
LS_SR_B_4	Landsat surface reflectance band 4	USGS ESPA High-level products. Five tiles. June, 2011	Water vegetation, soil and mineral spectral reflection (Baker et al. 2016)
LS_SR_B_5	Landsat surface reflectance band 5	USGS ESPA High-level products. Five tiles. June, 2012	Water vegetation, soil and mineral spectral reflection (Baker et al. 2016)
LS_SR_B_7	Landsat surface reflectance band 7	USGS ESPA High-level products. Five tiles. June, 2011	Soil and parent material mineralogy (Baker et al. 2016)
LS_SR_NI32	3/2 normalized surface reflectance band ratio.	USGS ESPA High-level products. Normalized index calculated as: (3-2)/(3+2)	Carbonates, geology (Baker et al. 2016)
LS_SR_NI52	5/2 normalized surface reflectance band ratio.	USGS ESPA High-level products. Normalized index calculated as: (5-2)/(5+2)	Geology, vegetation (Baker et al. 2016); Calcareous sedimentary rock. Sedimentary rocks intruded by tertiary volcanic rocks (skarns) (Ahrens, et al., 2008)

Environmental Variable	Description	Geoprocessing and Reference	Environmental Feature(s) Represented
LS_SR_NI57	5/7 normalized surface reflectance band ratio.	USGS ESPA High-level products. Normalized index calculated as: (5-7)/(5+7)	Gypsum (Ahrens, et al., 2008); soil and vegetation moisure content, surface salts (Baker et al., 2016)
northness	Northerly aspect	The northerly aspect of each cell was calculated by using the "northness" metric of Zar (1999), as follows: Northness = cos((aspect x pi)/180) This formula converts the aspects of 0°-360°, where 0° and 360° = north and 180° = south, into values between minus 1 and 1, where minus 1 = south and 1 = north. In this grid, high values are oriented more northerly than low values.	Temperature and Moisture
ph_m_0_5	Percent pH in soil, 0-5 cm	POLARIS soil data 3 arc second properties at: http://stream.princeton.edu/POLARIS/PROPERTIES/3arcsec/ ~ 90m resolution (resampled to 30m)	Soil and minerals
SEI_Evans	Site Exposure Index	The SEI rescales aspect to a north/south axis and weights it by Site Exposure Index steepness of the slope (Balice et al., 2000). The metric represents relative exposure ranging from -100 to 100 (coolest to warmest). Calculated using Geomorphometry & Gradient Metrics V. 2 Evans et al using 10 m resolution elevation data later aggregated to 30 m.	Temperature and Moisture
slope_dg	Slope (degrees)		Temperature and Moisture
SSW_Evans	Steady State Wetness Index	Steady state wetness index (Gessler et al., 1995; Moore et al., 1993), also know as Compound Topographic Index. The CTI is a function of both the slope and the upstream contributing area per unit width orthogonal to the flow direction and is a quantification of catenary topographic convergence. Calculated using Geomorphometry & Gradient Metrics V. 2 Evans et al using 10 m resolution elevation data later aggregated to 30 m.	Soil Moisture

APPENDIX F

FRISCO BUCKWHEAT, OSTLER'S PEPPERGRASS, AND FRISCO CLOVER

RECOMMENDED CONSERVATION MEASURES FOR INDIVIDUAL PLANT POPULATIONS TO IMPROVE FUTURE POPULATION CONDITION

We identify conservation measures to improve the population condition based on our future condition metrics (Table 25 of the SSA or Appendix A) with less extensive future stone mining and precious metal exploration and mining.

<u>Stone Mining Stressor – Scenarios 3 (Moderate Level Stone Mining) and 4 (High Level Stone and Precious Metal Mining)</u>

- *Frisco buckwheat and Ostler's peppergrass Cupric Mine populations* – To maintain a Moderate population condition for these species in the future, the following conservation measures are needed:

    - **Habitat Quality:** Undisturbed habitat quality needs to be in Good condition to maintain an overall Moderate population condition. Areas of disturbance should be in at least Moderate condition to prevent nonnative invasive species establishment above trace amounts. Reclamation of disturbed areas is implemented to maintain the suitable substrate conditions that support the species needs and maintain a Moderate category for habitat quality within mine areas. Reclamation practices are developed and implemented to facilitate re-establishment of the species on reclaimed soils.

    - **Habitat Area:** Remaining intact habitat area is large enough to meet at least the Moderate condition category that is not at risk of slope subsidence (26 acres or more of habitat area).

    - **Population Size:** Population size needs to remain in the Moderate condition category (500 to 5,000 individuals).

    - **Habitat Loss:** Habitat loss cannot exceed ten percent for Ostler's peppergrass to maintain a Moderate condition category for habitat area. Habitat loss can exceed ten percent for Frisco buckwheat.

    - **Other:** While we did not evaluate this at the population level, preservation of the genetic diversity of the population prior to mining activities and plant establishment to offset mining impacts is needed to support representation (adaptive capacity) at the species-level.

Frisco buckwheat and Ostler's peppergrass San Francisco populations **–** To maintain a Good population condition for these species in the future, the following conservation measures are needed:

- *Frisco buckwheat –*
  - **Habitat Quality:** Undisturbed habitat quality should be in Good condition. Areas of disturbance should be in Moderate or Good condition to prevent nonnative invasive species establishment above trace amounts. Reclamation of disturbed areas is implemented to maintain the suitable substrate conditions that support the species' needs and prevents nonnative invasive species establishment above trace amounts. Reclamation practices are developed and implemented to facilitate re-establishment of the species on reclaimed soils.
  - **Habitat Area:** Remaining intact habitat area is large enough to meet the Good condition category that is not at risk of slope subsidence (51 acres or more of habitat area).
  - **Population Size:** Population size needs to remain in the Good condition category (greater than 5,000 individuals).
  - **Habitat Loss:** Future stone mining would result in 10 percent or less habitat loss in the population. There will be no stone mining at the Old Quarry.
  - **Other:** While we did not evaluate this at the population level, preservation of the genetic diversity of the population prior to mining activities and plant establishment to offset mining impacts is needed to support representation (adaptive capacity) at the species-level.
- *Ostler's peppergrass –*
  - **Habitat Quality:** Undisturbed habitat quality should be in Good condition. Areas of disturbance should be in Moderate or Good condition that prevents nonnative invasive species establishment above trace amounts. Reclamation of disturbed areas is implemented to maintain the suitable substrate conditions that support the species' needs and prevents nonnative invasive species establishment above trace amounts. Reclamation practices are developed and implemented to facilitate re-establishment of the species on reclaimed soils.
  - **Habitat Area:** Remaining intact habitat area for the San Francisco population should not be at risk of slope subsidence and at least remain in the Moderate category for habitat area (26 to 50 ac in size).
  - **Population Size:** Population size needs to remain in the Good condition category (greater than 5,000 individuals).

- **Habitat Loss:** Future stone mining results in less than 5 percent habitat loss in the population to remain in the Good condition category. There will be no stone mining at the Old Quarry.

- **Other:** While we did not evaluate this at the population level, preservation of the genetic diversity of the population prior to mining activities and plant establishment to offset mining impacts is needed to support representation (adaptive capacity) at the species-level.

- *Frisco clover Blue Mountain Population* **–** To maintain a Moderate population condition in the future, the following conservation measures are needed:

    - **Habitat Quality:** Undisturbed habitat quality should be in Good condition. Areas of disturbance should be in Moderate or Good condition that prevents nonnative invasive species establishment above trace amounts. Reclamation of disturbed areas is implemented to maintain the suitable substrate conditions that support the species' needs and prevents nonnative invasive species establishment above trace amounts. Reclamation practices are developed and implemented to facilitate re-establishment of the species on reclaimed soils.

    - **Habitat Area:** Remaining intact habitat area for the Blue Mountain population should not be at risk of slope subsidence. The current Low condition category will not change.

    - **Population Size:** The current Low condition category will not change.

    - **Habitat Loss:** Future stone mining results in less than 5 percent habitat loss in the population to remain in the Good condition category.

    - **Other:** While we did not evaluate this at the population level, preservation of the genetic diversity of the population prior to mining activities and plant establishment to offset mining impacts is needed to support representation (adaptive capacity) at the species-level.

    - **Note:** Any future stone mining or slope subsidence in the population is a concern due to the currently small size and habitat area. Given the risk of slope subsidence for this population, avoidance of stone mining impacts is recommended.

<u>Precious Metal Exploration and Mining Stressor – Scenario 4 (High Level Stone and Precious Metal Mining)</u>

- *Frisco buckwheat* – To maintain a Good population condition in the future, the following conservation measures are needed:

  - **Habitat Quality:** Undisturbed habitat quality should be in Good condition. Areas of disturbance should be in Moderate or Good condition that prevents nonnative invasive species establishment above trace amounts. Reclamation of disturbed areas is implemented to maintain the suitable substrate conditions that support the species' needs and maintain a Moderate category for habitat quality within mine areas. Reclamation practices are developed and implemented to facilitate re-establishment of the species on reclaimed soils.

  - **Habitat Area:** Remaining intact habitat area is large enough to meet the Good or Moderate condition category that is not at risk of slope subsidence (51 acres or more of habitat area).

  - **Population Size:** A Good condition category is maintained for population size (greater than 5,000 individuals).

  - **Habitat Loss:** Future stone mining results in less than 10 percent habitat loss to remain in the Good or Moderate condition category.

  - **Other:** While we did not evaluate this at the population level, preservation of the genetic diversity of the population prior to mining activities and plant establishment to offset mining impacts is needed to support representation (adaptive capacity) at the species-level.

- *Ostler's peppergrass* – To maintain a Good population condition in the future, the following conservation measures are needed:

  - **Habitat Quality:** Undisturbed habitat quality should be in Good condition. Areas of disturbance should be in Moderate or Good condition that prevents nonnative invasive species establishment above trace amounts. Reclamation of disturbed areas is implemented to maintain the suitable substrate conditions that support the species' needs and prevents nonnative invasive species establishment above trace amounts. Reclamation practices are developed and implemented to facilitate re-establishment of the species on reclaimed soils.

  - **Habitat Area:** Remaining intact habitat area is large enough to meet the Good condition category that is not at risk of slope subsidence (51 acres or more of habitat area).

  - **Population Size:** Population size needs to remain in the Moderate condition category (500 to 5,000 individuals).

- **Habitat Loss:** Future stone mining results in less than 10 percent habitat loss to remain in the Good or Moderate condition category.

- **Other:** While we did not evaluate this at the population level, preservation of the genetic diversity of the population prior to mining activities and plant establishment to offset mining impacts is needed to support representation (adaptive capacity) at the species-level.

- *Frisco clover* – To maintain a Good population condition in the future, the following conservation measures are needed:

  - **Habitat Quality:** Undisturbed habitat quality should be in Good or Moderate condition. Areas of disturbance should be in Moderate condition that prevents nonnative invasive species establishment above trace amounts. Reclamation of disturbed areas is implemented to maintain the suitable substrate conditions that support the species' needs and maintain a Moderate category for habitat quality within mine areas. Reclamation practices are developed and implemented to facilitate re-establishment of the species on reclaimed soils.

  - **Habitat Area:** Remaining intact habitat area is large enough to meet the Good condition category that is not at risk of slope subsidence (51 acres or more of habitat area).

  - **Population Size:** Population size needs to remain in the Moderate condition category (500 to 5,000 individuals).

  - **Habitat Loss:** Future stone mining results in less than 10 percent habitat loss to remain in the Good or Moderate condition category.

  - **Other:** While we did not evaluate this at the population level, preservation of the genetic diversity of the population prior to mining activities and plant establishment to offset mining impacts is needed to support representation (adaptive capacity) at the species-level.